CHEMISTRY

IN ITS APPLICATION

TO

AGRICULTURE AND PHYSIOLOGY.

BY

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EDITED FROM THE MANUSCRIPT OF THE AUTHOR

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Second Edition.

WITH VERY NUMEROUS ADDITIONS.

THE BRITISH ASSOCIATION

ADVANCEMENT OF SCIENCE.

ONE of the most remarkable features of modern times
ꜱ the combination of large numbers of individuals repre-
ꜱting the whole intelligence of nations for the express
pose of advancing science by their united efforts, of
learning its progress, and of communicating new disco-
veries. The formation of such associations is, in itself,
an evidence that they were needed.

It is not every one who is called by his situation in life
to assist in extending the bounds of science ; but all
mankind have a claim to the blessings and benefits which
accrue from its earnest cultivation. The foundation of
scientific institutions is an acknowledgment of these
benefits, and this acknowledgment proceeding from whole
nations may be considered as the triumph of mind over
empiricism.

Innumerable are the aids afforded to the means of life,
to manufactures, and to commerce, by the truths which

assiduous and active inquirers have discovered and ren-
dered capable of practical application. But it is not the
mere practical utility of these truths which is of importance.
Their influence upon mental culture is most beneficial;
and the new views acquired by the knowledge of them
enable the mind to recognise, in the phenomena of nature,
proofs of an Infinite Wisdom, for the unfathomable pro-
fundity of which language has no expression.

At one of the meetings of the chemical section of the
" British Association for the Advancement of Science,"
the honourable task of preparing a Report upon the state
of Organic Chemistry was imposed upon me. In the
present work I present the Association with a part of this
report.

I have endeavoured to develop, in a manner corres-
pondent to the present state of science, the fundamental
principles of Chemistry in general, and the laws of
Organic Chemistry in particular, in their applications to
Agriculture and Physiology; to the causes of fermenta-
tion, decay, and putrefaction; to the vinous and acetous
fermentations, and to nitrification. The conversion of
woody fibre into wood and mineral-coal, the nature of
poisons, contagions, and miasms, and the causes of their
action on the living organism, have been elucidated in
their chemical relations.

I shall be happy if I succeed in attracting the attention
of men of science to subjects which so well merit to
engage their talents and energies. Perfect Agriculture
is the true foundation of all trade and industry—it is the

foundation of the riches of states. But a rational system
of Agriculture cannot be formed without the application of
scientific principles; for such a system must be based on
an exact acquaintance with the means of nutrition of
vegetables, and with the influence of soils and action of
manure upon them. This knowledge we must seek from
chemistry, which teaches the mode of investigating the
composition and of studying the characters of the differ-
ent substances from which plants derive their nourish-
ment.

The chemical forces play a part in all the processes of
the living animal organism; and a number of transforma-
tions and changes in the living body are exclusively
pendent on their influence. The diseases incident to
the period of growth of man, contagion and contagi-
ous matters, have their analogues in many chemical pro-
cesses. The investigation of the chemical connexion
subsisting between those actions proceeding in the living
body, and the transformations presented by chemical com-
pounds, has also been a subject of my inquiries. A per-
fect exhaustion of this subject, so highly important to
medicine, cannot be expected without the co-operation of
physiologists. Hence I have merely brought forward the
purely chemical part of the inquiry, and hope to attract
attention to the subject.

Since the time of the immortal author of the " Agricul-
tural Chemistry," no chemist has occupied himself in
studying the applications of chemical principles to the
growth of vegetables, and to organic processes. I have

endeavoured to follow the path marked out by Sir Humphry Davy, who based his conclusions only on that which was capable of inquiry and proof. This is the path of true philosophical inquiry, which promises to lead us to truth—the proper object of our research.

In presenting this report to the British Association I feel myself bound to convey my sincere thanks to Dr. Lyon Playfair, of St. Andrew's, for the active assistance which has been afforded me in its preparation by that intelligent young chemist during his residence in Giessen. I cannot suppress the wish that he may succeed in being as useful, by his profound and well-grounded knowledge of chemistry, as his talents promise.

JUSTUS LIEBIG.

GIESSEN,
September 1, 1840.

EDITOR'S PREFACE.

THE former edition of this work was prepared in the form of a report on the present state of Organic Chemistry. The state of a science such as this could not be exhibited by a systematic treatise on organic compounds, but by showing that the science was so far advanced as to be useful in its practical applications.

The work was written by a Chemist, and addressed to Chemists. The author did not flatter himself that his opinions would be so eagerly embraced by agriculturists, as circumstances have shown to be the case. Hence his language and style were less adapted for them than for those who are conversant with the abstract details of chemical science. But the eager reception of the work by agriculturists has shown that they possess an ardent desire to profit by the aids offered to them by Chemistry. It, therefore, became necessary to adapt the work for

years have, however, sufficed to throw much light upon this interesting department of science, and numerous facts have been discovered which cannot fail to be of importance in their practical applications.

The peculiar object of organic chemistry is to discover the chemical conditions essential to the life and perfect development of animals and vegetables, and generally to investigate all those processes of organic nature which are due to the operation of chemical laws. Now, the continued existence of all living beings is dependent on the reception by them of certain substances, which are applied to the nutrition of their frame. An inquiry, therefore, into the conditions on which the life and growth of living beings depend, involves the study of those substances which serve them as nutriment, as well as the investigation of the sources whence these substances are derived, and the changes which they undergo in the process of assimilation.

A beautiful connexion subsists between the organic and inorganic kingdoms of nature. Inorganic matter affords food to plants, and they, on the other hand, yield the means of subsistence to animals. The conditions necessary for animal and vegetable nutrition are essentially different. An animal requires for its development, and for the sustenance of its vital functions, a certain class of substances which can only be generated by organic beings possessed of life. Although many animals are entirely carnivorous, yet their primary nutriment must be derived from plants; for the animals upon which they subsist receive their nourishment from vegetable matter. But plants find new nutritive material only in inorganic substances. Hence one great end of vegetable life is to generate matter adapted for the nutrition of animals out

of inorganic substances, which are not fitted for this purpose. Now the purport of this work is, to elucidate the chemical processes engaged in the nutrition of vegetables.

The first part of it will be devoted to the examination of the matters which supply the nutriment of plants, and of the changes which these matters undergo in the living organism. The chemical compounds which afford to plants their principal constituents, viz., carbon and nitrogen, will here come under consideration, as well as the relations in which the vital functions of vegetables stand to those of the animal economy and to other phenomena of nature.

The second part of the work will treat of the chemical processes which effect the complete destruction of plants · and animals after death, such as the peculiar modes of decomposition, usually described as *fermentation, putrefaction,* and *decay* ; and in this part the changes which organic substances undergo in their conversion into inorganic compounds, as well as the causes which determine these changes, will become matter of inquiry.

PART I.

OF THE CHEMICAL PROCESSES IN THE NUTRITION OF VEGETABLES.

CHAPTER I.

OF THE CONSTITUENT ELEMENTS OF PLANTS.

THE ultimate constituents of plants are those which form organic matter in general, namely, Carbon, Hydrogen, Nitrogen, and Oxygen. These elements are always present in plants, and produce by their union the various proximate principles of which they consist. It is, therefore, necessary to be acquainted with their individual characters, for it is only by a correct appreciation of these that we are enabled to explain the functions which they perform in the vegetable organisation.

Carbon is an elementary substance, endowed with a considerable range of affinity. With oxygen it unites in two proportions, forming the gaseous compounds known under the names of carbonic acid and carbonic oxide. The former of these is emitted in immense quantities from many volcanoes and mineral springs, and is a product of the combustion and decay of organic matter. It is subject to be decomposed by various agencies, and its elements then arrange themselves into new combinations.

Carbon·is familiarly known as *charcoal,* but in this state it is mixed with several earthy bodies ; in a state of absolute purity it constitutes the diamond.

Hydrogen is a very important constituent of vegetable matter. It possesses a special affinity for oxygen, with which it unites and forms water. The whole of the phenomena of decay depend upon the exercise of this affinity, and many of the processes engaged in the nutrition of plants originate in the attempt to gratify it. Hydrogen, when in the state of a gas, is very combustible, and the lightest body known; but it is never found in nature in an isolated condition. Water is the most common combination in which it is presented; and it may be removed by various processes from the oxygen, with which it is united in this body.

Nitrogen is quite opposed in its chemical characters to the two bodies now described. Its principal characteristic is an indifference to all other substances, and an apparent reluctance to enter into combination with them. When forced by peculiar circumstances to do so, it seems to remain in the combination by a *vis inertiæ;* and very slight forces effect the disunion of these feeble compounds.

Yet nitrogen is an invariable constituent of plants, and during their life is subject to the control of the vital powers. But when the mysterious principle of life has ceased to exercise its influence, this element resumes its chemical character, and materially assists in promoting the decay of vegetable matter, by escaping from the compounds of which it formed a constituent.

Oxygen, the only remaining constituent of organic matter, is a gaseous element, which plays a most important part in the economy of nature. It is the agent employed in effecting the union and disunion of a vast

number of compounds. It is superior to all other elements
in the extensive range of its affinities. The phenomena
of combustion and decay are examples of the exercise of
its power.

Oxygen is the most generally diffused element on the
surface of the earth ; for, besides constituting the prin-
cipal part of the atmosphere which surrounds it, it is a
component of almost all the earths and minerals found
on its surface. In an isolated state it is a gaseous body,
possessed of neither taste nor smell. It is slightly soluble
in water, and hence is usually found dissolved in rain
and snow, as well as in the water of running streams.

Such are the principal characters of the elements
which constitute organic matter; but it remains for us to
consider in what form they are united in plants.

The substances which constitute the principal mass of
every vegetable are compounds of carbon with oxygen
and hydrogen, in the proper relative proportions for
forming water. Woody fibre, starch, sugar, and gum,
for example, are such compounds of carbon with the
elements of water. In another class of substances con-
taining carbon as an element, oxygen and hydrogen are
again present ; but the proportion of oxygen is greater
than would be required for producing water by union
with the hydrogen. The numerous organic acids met
with in plants belong, with few exceptions, to this class.

A third class of vegetable compounds contains carbon
and hydrogen, but no oxygen, or less of that element
than would be required to convert all the hydrogen into
water. These may be regarded as compounds of carbon
with the elements of water, and an excess of hydrogen.
Such are the volatile and fixed oils, wax, and the resins.
Many of them have acid characters.

The •juices of all vegetables contain organic acids, generally combined with the inorganic bases, or metallic oxides: for these metallic oxides exist in every plant, and may be detected in its ashes after incineration.

'. *Nitrogen* is an element of vegetable albumen and gluten; it is a constituent of the acid, and of what are termed the "indifferent substances" of plants, as well as of those peculiar vegetable compounds which possess all the properties of metallic oxides, and are known as "organic bases."

Estimated by its proportional weight, nitrogen forms only a very small part of plants: but it is never entirely absent from any part of them. Even when it does not absolutely enter into the composition of a particular part or organ, it is always to be found in the fluids which pervade it.

It follows from the facts thus far detailed, that the development of a plant requires the presence, first, of substances containing carbon and nitrogen, and capable of yielding these elements to the growing organism; secondly, of water and its elements; and lastly, of a soil to furnish the inorganic matters which are likewise essential to vegetable life.

OF THE COMPOSITION OF THE ATMOSPHERE.

In the normal state of growth plants can only derive their nourishment from the atmosphere and the soil. Hence it is of importance to be acquainted with the composition of these, in order that we may be enabled to judge from which of their constituents the nourishment is afforded.

The composition of the atmosphere has been examined

by many chemists with great care, and the results of their researches have shown, that its principal constituents are always present in the same proportion. These are the two gases, oxygen and nitrogen, the general properties of which have been already described. One hundred parts, by weight, of atmospheric air contain 23·1 parts of oxygen, and 76·9 parts of nitrogen; or 100 volumes of air contain nearly 21 volumes of oxygen gas. From the extensive range of affinity which this gas possesses, it is obvious, that were it alone to constitute our atmosphere, aud left unchecked to exert its powerful effects, all nature would be one scene of universal destruction. It is on this account that nitrogen is present in the air in so large proportion. It is peculiarly adapted for this purpose, as it does not possess any disposition to unite with oxygen, and exerts no action upon the processes proceeding on the earth. These two gases are intimately mixed, by virtue of a property which all gases possess in common, of diffusing themselves equally through every part of another gas, with which they are placed in contact.

Although oxygen and nitrogen form the principal constituents of the atmosphere, yet they are not the only substances found in it. Watery vapour and carbonic acid gas materially modify its properties. The former of these falls upon the earth as rain, and brings with it any soluble matter which it meets in its passage through the air.

Carbonic acid gas is discharged in immense quantities from the active volcanoes of America, and from many of the mineral springs which abound in various parts of Europe; it is also generated during the combustion and decay of organic matter. It is not, therefore, surprising that it should have been detected in every part of the

atmosphere in which its presence has been looked for.
Saussure found it even in the air on the summit of Mont
Blanc, which is covered with perpetual snow, and where
it could not have been produced by the immediate agency
of vegetable matter.   Carbonic acid gas performs a most
important part in the process of vegetable nutrition, the
consideration of which belongs to another part of the work.

Carbonic acid, water, and ammonia (a compound of
hydrogen and nitrogen) are the final products of the decay
of animal and vegetable matter.   In an isolated condition,
they usually exist in the gaseous form.   Hence, on their
formation, they must escape into the atmosphere.   But
ammonia has not hitherto been enumerated amongst the
constituents of the air, although, according to our view,
it can never be absent.   The reason of this is, that it
exists in extremely minute quantity in the amount of air
usually subjected to experiment in chemical analysis; it
has consequently escaped detection.   But rain which
falls through a large extent of air, carries down in solu-
tion all that remains in suspension in it.   Now ammonia
always exists in rain-water, and from this fact we must
conclude that it is invariably present in the atmosphere.
Nor can we be surprised at its presence when we consider
that many volcanoes now in activity emit large quantities
of it.   This subject will, however, be discussed more
fully in another part of the work.

Such are the principal constituents of the atmosphere
from which plants derive their nourishment; for although
other matters are supposed to exist in it in minute
quantity, yet they do not exercise any influence on
vegetation, nor has even their presence been satisfactorily
demonstrated.

OF SOILS.

A soil may be considered a magazine of inorganic matters, which are prepared by the plant to suit the purposes destined for them in its nutrition. The composition and uses of such substances cannot, however, be studied with advantage, until we have considered the manner in which the organic matter is obtained by plants.

Some virgin soils, such as those of America, contain vegetable matter in large proportion ; and as these have been found eminently adapted for the cultivation of most plants, the organic matter contained in them has naturally been recognised as the cause of their fertility. To this matter, the term " vegetable mould " or *humus* has been applied. Indeed, this peculiar substance appears to play such an important part in the phenomena of vegetation, that vegetable physiologists have been induced to ascribe the fertility of every soil to its presence. It is believed by many to be the principal nutriment of plants, and is supposed to be extracted by them from the soil in which they grow. It is itself the product of the decay of vegetable matter, and must therefore contain many of the constituents which are found in plants during life. Its action will therefore be examined in considering whence hese constituents are derived.

CHAPTER II.

OF THE ASSIMILATION OF CARBON.

COMPOSITION OF HUMUS.

THE humus, to which allusion has been made, is described by chemists as a brown substance easily soluble in alkalies, but only slightly so in water, and produced during the decomposition of vegetable matters by the action of acids or alkalies. It has, however, received various names according to the different external characters and chemical properties which it presents. Thus, *ulmin*, *humic acid*, *coal of humus*, and *humin*, are names applied to modifications of *humus*. They are obtained by treating peat, woody fibre, soot, or brown coal with alkalies; by decomposing sugar, starch, or sugar of milk by means of acids; or by exposing alkaline solutions of tannic and gallic acids to the action of the air.

The modifications of *humus* which are soluble in alkalies, are called *humic acid;* while those which are insoluble have received the designations of *humin* and *coal of humus*.

The names given to these substances might cause it to be supposed that their composition is identical. But a more erroneous notion could not be entertained; since even sugar, acetic acid, and resin do not differ more widely in the proportions of their constituent elements, than do the various modifications of *humus*.

Humic acid formed by the action of hydrate of potash

upon sawdust contains, according to the accurate analysis of Peligot, 72 per cent. of carbon, while the humic acid obtained from turf and brown coal contains, according to Sprengel, only 58 per cent. ; that produced by the action of dilute sulphuric acid upon sugar, 57 per cent. according to Malaguti; and that, lastly, which is obtained from sugar or from starch, by means of muriatic acid, according to the analysis of Stein, 64 per cent. All these analyses have been repeated with care and accuracy, and the proportion of carbon in the respective cases has been found to agree with the estimates of the different chemists above mentioned ; so that there is no reason to ascribe the difference in this respect between the varieties of *humus* to the mere difference in the methods of analysis or degrees of expertness of the operators. Malaguti states, moreover, that *humic acid* contains an equal number of equivalents of oxygen and hydrogen, that is to say, that these elements exist in it in the proportions for forming water ; while, according to Sprengel, the oxygen is in excess, and Peligot even estimates the quantity of oxygen at 14 equivalents, and the hydrogen at only 6 equivalents, making the deficiency of hydrogen as great as 8 equivalents. And although Mulder * has very recently explained many of these conflicting results, by showing that there are several kinds of humus and humic acids essentially distinct in their characters, and fixed in their composition, yet he has afforded no proof that the definite compounds obtained by him really exist, as such, in the soil. On the contrary, they appear to have been formed by the action of the potash and ammonia, which he employed in their preparation.

It is quite evident, therefore, that chemists have been

* Bulletin des Scienc. Phys. et Natur. de Neerl. 1840, p. 1—102.

in the habit of designating all products of the decomposition of organic bodies which had a brown or brownish-black colour by the names of *humic acid* or *humin*, according as they were soluble or insoluble in alkalies; although in their composition and mode of origin, the substances thus confounded might be in no way allied.

Not the slightest ground exists for the belief that one or other of these artificial products of the decomposition of vegetable matters exists in nature in the form and endowed with the properties of the vegetable constituents of mould; there is not the shadow of a proof that one of them exerts any influence on the growth of plants either in the way of nourishment or otherwise.

Vegetable physiologists have, without any apparent reason, imputed the known properties of the *humus* and *humic acids* of chemists to that constituent of mould which has received the same name, and in this way have been led to their theoretical notions respecting the functions of the latter substance in vegetation.

The opinion that the substance called *humus* is extracted from the soil by the roots of plants, and that the carbon entering into its composition serves in some form or other to nourish their tissues, is considered by many as so firmly established that any new argument in its favour has been deemed unnecessary; the obvious difference in the growth of plants according to the known abundance or scarcity of *humus* in the soil, seemed to afford incontestable proof of its correctness*.

Yet, this position, when submitted to a strict examina-

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* This remark applies more to German than to English botanists and physiologists. In England, the idea that humus, as such, affords nourishment to plants is by no means general; but on the Continent, the views of Berzelius on this subject have been almost universally adopted.—ED.

tion, is found to be untenable, and it becomes evident
from most conclusive proofs that *humus* in the form in
which it exists in the soil, does not yield the smallest
nourishment to plants.

The adherence to the above incorrect opinion has
hitherto rendered it impossible for the true theory of the
nutritive process in vegetables to become known, and has
thus deprived us of our best guide to a rational practice
in agriculture.   Any great improvement in that most
important of all arts is inconceivable without a deeper and
more perfect acquaintance with the substances which
nourish plants, and with the sources whence they are
derived ; and no other cause can be discovered to account
for the fluctuating and uncertain state of our knowledge
on this subject up to the present time, than that modern
physiology has not kept pace with the rapid progress of
chemistry.

In the following inquiry we shall suppose the *humus*
of vegetable physiologists to be really endowed with the
properties recognised by chemists in the brownish-black
deposits which they obtain by precipitating an alkaline
decoction of mould or peat by means of acids, and which
they name *humic acid.*

Humic acid, when first precipitated, is a flocculent sub-
stance, is soluble in 2500 times its weight of water, and
combines with alkalies, lime and magnesia, forming com-
pounds of the same degree of solubility. (Sprengel.)

Vegetable physiologists agree in the supposition that
by the aid of water *humus* is rendered capable of being
absorbed by the roots of plants.   But according to the
observation of chemists, humic acid is soluble only when
newly precipitated, and becomes completely insoluble
when dried in the air, or when exposed in the moist state
to the freezing temperature. (Sprengel.)

Both the cold of winter and the heat of summer there-
fore are destructive of the solubility of humic acid, and at
the same time of its capability of being assimilated by
plants. So that, if it is absorbed by plants, it must be in
some altered form.

The correctness of these observations is easily demon-
strated by treating a portion of good mould with cold
water. The fluid remains colourless, and is found to
have dissolved less than 100,000 part of its weight of
organic matters, and to contain merely the salts which
are present in rain-water.

Decayed oak-wood, likewise, of which humic acid is
the principal constituent, was found by Berzelius to yield
to cold water only slight traces of soluble materials: and
I have myself verified this observation on the decayed
wood of beech and fir.

These facts, which show that humic acid, in its unal-
tered condition, cannot serve for the nourishment of
plants, have not escaped the notice of physiologists; and
hence they have assumed that the lime or the different
alkalies found in the ashes of vegetables render soluble
the humic acid and fit it for the process of assimilation.

Alkalies and alkaline earths do exist in the different
kinds of soil in sufficient quantity to form such soluble
compounds with the humic acid.

Now, let us suppose that humic acid is absorbed by
plants in the form of that salt which contains the largest
proportion of humic acid, namely, in the form of humate
of lime, and then from the known quantity of the alkaline
bases contained in the ashes of plants, let us calculate the
amount of humic acid which might be assimilated in this
manner. Let us admit, likewise, that potash, soda, and
the oxides of iron and manganese have the same capacity

of saturation as lime with respect to humic acid, and then
we may take as the basis of our calculation the analysis
of M. Berthier, who found that 1000 lbs. of dry fir-wood
yielded 4 lbs. of ashes, and that in every 100 lbs. of these
ashes, after the chloride of potassium and sulphate of
potash were extracted, 53 lbs. consisted of the basic
metallic oxides, potash, soda, lime, magnesia, iron, and
manganese.

One Hessian acre * of woodland yields annually,
according to Dr. Heyer, on an average, 2920 lbs. of
dry fir-wood, which contains 6·17 lbs. of metallic oxides.

Now, according to the estimates of Malaguti and
Sprengel, 1 lb. of lime combines chemically with 12 lbs.
of humic acid ; 6·17 lbs. of the metallic oxides would
accordingly introduce into the trees 67 lbs. of humic acid,
which, admitting humic acid to contain 58 per cent. of
carbon, would correspond to 100 lbs. of dry wood.   But
we have seen that 2920 lbs. of fir-wood are really
produced.

Again, if the quantity of humic acid which might be
introduced into wheat in the form of humates is calculated
from the known proportion of metallic oxides existing in
wheat straw (the sulphates and chlorides also contained
in the ashes of the straw not being included), it will be
found that the wheat growing on 1 Hessian acre would
receive in that way 63 lbs. of humic acid, corresponding
to 93·6 lbs. of woody fibre.   But the extent of land just
mentioned produces, independently of the roots and grain,
1961 lbs. of straw, the composition of which is the same
as that of woody fibre.

It has been taken for granted in these calculations that

* One Hessian acre is equal to 40,000 square feet, Hessian, or 26,910
square feet, English measure.

the basiç metallic oxides which have served to introduce humic acid into the plants do not return to the soil, since it is certain that they remain fixed in the parts newly formed during the process of growth.

· Let us now calculate the quantity of humic acid which plants can receive under the most favourable circumstances, viz. through the agency of rain-water.

The quantity of rain which falls at Erfurt, one of the most fertile districts of Germany, during the months of April, May, June, and July, is stated by Schubler to be 19·3 lbs. over every square foot of surface; 1 Hessian acre, or 26,910 square feet, consequently receive 771,000 lbs. of rain-water.

If, now, we suppose that the whole quantity of this rain is taken up by the roots of a summer plant, which ripens four·months after it is planted, so that not a pound of this water evaporates except from the leaves of the plant; and if we further assume that the water thus absorbed is saturated with humate of lime (the most soluble of the humates, and that which contains the largest proportion of humic acid); then the plants thus nourished would not receive more than 330 lbs. of humic acid, since one part of humate of lime requires 2500 parts of water for solution.

But the extent of land which we have mentioned produces 2843 lbs. of corn (in grain and straw, the roots not included), or 22,000 lbs. of beet-root (without the leaves and small radicle fibres). It is quite evident that the 330 lbs. of humic acid, supposed to be absorbed, cannot account for the quantity of carbon contained in the roots and leaves alone, even if the supposition were correct, that the whole of the rain-water was absorbed by the plants. But since it is known that only a small portion

of the rain-water which falls upon the surface of the earth evaporates through plants, the quantity of carbon which can be conveyed into them in any conceivable manner by means of humic acid must be extremely trifling, in comparison with that actually produced in vegetation.

Other considerations of a higher nature confute the common view respecting the nutritive office of humic acid, in a manner so clear and conclusive that it is difficult to conceive how it could have been so generally adopted.

Fertile land produces carbon in the form of wood, hay, grain, and other kinds of growth, the masses of which differ in a remarkable degree.

2920 lbs. of firs, pines, beeches, &c. grow as wood upon one Hessian acre of forest-land with an average soil. The same superficies yields 2755 lbs. of hay.

A similar surface of corn-land gives from 19,000 to 22,000 lbs. of beet-root, or 881 lbs. of rye, and 1961 lbs. of straw, 160 sheaves of 15·4 lbs. each,—in all, 2843 lbs.

One hundred parts of dry fir-wood contain 38 parts of carbon; therefore, 2920 lbs. contain 1109 lbs. of carbon.

One hundred parts of hay*, dried in air, contain 44·31 parts carbon. Accordingly, 2755 lbs. of hay contain 1111 lbs. of carbon.

Beet-roots contain from 89 to 89·5 parts water, and from 10·5 to 11 parts solid matter, which consists of from 8 to 9 per cent. sugar, and from 2 to 2½ per cent. cellular tissue. Sugar contains 42·4 per cent.; cellular tissue, 47 per cent. of carbon.

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* 100 parts of hay, dried at 100° C. (212° F.) and burned with oxide of copper in a stream of oxygen gas, yielded 51·93 water, 165·8 carbonic acid, and 6·82 of ashes. This gives 45·87 carbon, 5·76 hydrogen, 31·55 oxygen, and 6·82 ashes. Hay, dried in the air, loses 11·2 p. c. water at 100° C. (212° F.)—(*Dr. Will.*)

22,000 lbs. of beet-root, therefore, if they contain 9 per cent. of sugar, and 2 per cent. of cellular tissue, would yield 1032 lbs. of carbon, of which 833 lbs. would be due to the sugar, and 198 lbs. to the cellular tissue ; the carbon of the leaves and small roots not being included in the calculation.

One hundred parts of straw*, dried in air, contain 38 per cent. of carbon ; therefore 1961 lbs. of straw contain 745 lbs. of carbon. One hundred parts of corn contain 43 parts of carbon ; 882 lbs. must therefore contain 379 lbs.—in all, 1124 lbs. of carbon.

26,910 square feet of wood and meadow land produce, consequently, 1109 lbs. of carbon; while the same extent of arable land yields in beet-root, without leaves, 1032 lbs., or in corn, 1124 lbs.

It must be concluded from these incontestable facts that equal surfaces of cultivated land of an average fertility produce equal quantities of carbon ; yet, how unlike have been the different conditions of the growth of the plants from which this has been deduced !

Let us now inquire whence the grass in a meadow, or the wood in a forest, receives its carbon, since there no manure—no carbon—has been given to it as nourishment ? and how it happens, that the soil, thus exhausted, instead of becoming poorer, becomes every year richer in this element?

A certain quantity of carbon is taken every year from the forest or meadow, in the form of wood or hay, and, in spite of this, the quantity of carbon in the soil augments ; it becomes richer in humus.

* Straw analysed in the same manner, and dried at 100° C., gave 46·37 p. c. of carbon, 5·68 p. c. of hydrogen, 43·93 p. c. of oxygen, and 4·02 p. c. of ashes. Straw dried in the air at 100° C. lost 18 p. c. of water.—(Dr. Will.)

—appears quite incomprehensible, unless some source exists whence the oxygen abstracted is replaced. How does it happen, then, that the proportion of oxygen in the atmosphere is thus invariable ?

The answer to this question depends upon another ; namely, what becomes of the carbonic acid, which is produced during the respiration of animals, and by the process of combustion ? A cubic foot of oxygen gas, by uniting with carbon so as to form carbonic acid, does not change its volume. The billions of cubic feet of oxygen extracted from the atmosphere, produce the same number of billions of cubic feet of carbonic acid, which immediately supply its place.

The most exact and most recent experiments of De Saussure, made in every season for a space of three years, have shown, that the air contains on an average 0·000415 of its own volume of carbonic acid gas ; so that, allowing for the inaccuracies of the experiments, which must diminish the quantity obtained, the proportion of carbonic acid in the atmosphere may be regarded as nearly equal to 1-1000 part of its weight. The quantity varies according to the seasons ; but the yearly average remains continually the same.

We have no reason to believe that this proportion was less in past ages ; and nevertheless, the immense masses of carbonic acid which annually flow into the atmosphere from so many causes, ought perceptibly to increase its quantity from year to year. But we find that all earlier observers describe its volume as from one-half to ten

oxygen. But the air is rendered incapable of supporting the process of respiration, when the quantity of its oxygen is decreased 12 per cent.; so that a thousand million men would make the air unfit for respiration in a million years. The consumption of oxygen by animals, and by the process of combustion, is not introduced into the calculation.

times greater than that which it has at the present time;
so that we can hence at most conclude that it has dimi-
nished.

It is quite evident that the quantities of carbonic acid
and oxygen in the atmosphere, which remain unchanged
by lapse of time, must stand in some fixed relation to one
another; a cause must exist which prevents the increase
of carbonic acid by removing that which is constantly
forming; and there must be some means of replacing the
oxygen, which is removed from the air by the processes
of combustion and putrefaction, as well as by the respira-
tion of animals.

Both these causes are united in the process of vegetable
life.

The facts which we have stated in the preceding pages
prove that the carbon of plants must be derived exclu-
sively from the atmosphere. Now, carbon exists in the
atmosphere only in the form of carbonic acid, and there-
fore in a state of combination with oxygen.

It has been already mentioned likewise, that carbon
and the elements of water form the principal constituents
of vegetables; the quantity of the substances which do
not possess this composition being in a very small propor-
tion.   Now, the relative quantity of oxygen in the whole
mass is less than in carbonic acid; for the latter contains
two equivalents of oxygen, whilst one only is required to
unite with hydrogen in the proportion to form water.
The vegetable products which contain oxygen in larger
proportion than this, are, comparatively, few in number;
indeed in many the hydrogen is in great excess.   It
is obvious, that when the hydrogen of water is assi-
milated by a plant, the oxygen in combination with
it must be liberated, and will afford a quantity of this

element sufficient for the wants of the plant. If this be the case, the oxygen contained in the carbonic acid is quite unnecessary in the process of vegetable nutrition, and it will consequently escape into the atmosphere in a gaseous form. It is therefore certain, that plants must possess the power of decomposing carbonic acid, since they appropriate its carbon for their own use. The formation of their principal component substances must necessarily be attended with the separation of the carbon of the carbonic acid from the oxygen, which must be returned to the atmosphere, whilst the carbon enters into combination with water or its elements. The atmosphere must thus receive a volume of oxygen for every volume of carbonic acid which has been decomposed.

This remarkable property of plants has been demonstrated in the most certain manner, and it is in the power of every person to convince himself of its existence. The leaves and other green parts of a plant absorb carbonic acid, and emit an equal volume of oxygen. They possess this property quite independently of the plant; for if, after being separated from the stem, they are placed in water containing carbonic acid, and exposed in that condition to the sun's light, the carbonic acid is, after a time, found to have disappeared entirely from the water. If the experiment is conducted under a glass receiver filled with water, the oxygen emitted from the plant may be collected and examined. When no more oxygen gas is evolved, it is a sign that all the dissolved carbonic acid is decomposed; but the operation recommences if a new portion of it is added.

Plants do not emit gas when placed in water which either is free from carbonic acid, or contains an alkali that protects it from assimilation.

These observations were first made by Priestley and Sennebier. The excellent experiments of De Saussure have further shown, that plants increase in weight during the decomposition of carbonic acid and separation of oxygen. This increase in weight is greater than can be accounted for by the quantity of carbon assimilated; a fact which confirms the view, that the elements of water are assimilated at the same time.

The life of plants is closely connected with that of animals, in a most simple manner, and for a wise and sublime purpose.

The presence of a rich and luxuriant vegetation may be conceived without the concurrence of animal life, but the existence of animals is undoubtedly dependent upon the life and development of plants.

Plants not only afford the means of nutrition for the growth and continuance of animal organization, but they likewise furnish that which is essential for the support of the important vital process of respiration; for besides separating all noxious matters from the atmosphere, they are an inexhaustible source of pure oxygen, which supplies the loss which the air is constantly sustaining. Animals on the other hand expire carbon, which plants inspire; and thus the composition of the medium in which both exist, namely, the atmosphere, is maintained constantly unchanged.

It may be asked—Is the quantity of carbonic acid in the atmosphere, which scarcely amounts to 1-10th per cent., sufficient for the wants of the whole vegetation on the surface of the earth,—is it possible that the carbon of plants has its origin from the air alone? This question is very easily answered. It is known, that a column of air of 2441 lbs. weight rests upon every square Hessian foot (=0.567 square foot English) of the sur-

face of the earth; the diameter of the earth and its super-
ficies are likewise known, so that the weight of the atmo-
sphere can be calculated with the greatest exactness.
The thousandth part of this is carbonic acid, which con-
tains upwards of 27 per cent. carbon. By this calculation
it can be shown, that the atmosphere contains 3306 billion
lbs. of carbon; a quantity which amounts to more than the
weight of all the plants, and of all the strata of mineral
and brown coal, which exist upon the earth.   This
carbon is, therefore, more than adequate to all the pur-
poses for which it is required.   The quantity of carbon
contained in sea-water is proportionally still greater.

If, for the sake of argument, we suppose the superficies
of the leaves and other green parts of plants, by which
the absorption of carbonic acid is effected, to be double
that of the soil upon which they grow, a supposition which
is much under the truth in the case of woods, meadows,
and corn-fields; and if we further suppose that carbonic
acid equal to 0.00067 of the volume of the air, or
1-1000th of its weight is abstracted from it during every
second of time, for eight hours daily, by a field of 53,814
square feet (= 2 Hessian acres); then those leaves
would receive 1102 lbs. of carbon in 200 days *.

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* The quantity of carbonic acid which can be extracted from the air in
a given time, is shown by the following calculation. During the white-
washing of a small chamber, the superficies of the walls and roof of which
we will suppose to be 105 square metres, and which receives six coats of
lime in four days, carbonic acid is abstracted from the air, and the lime is
consequently converted, on the surface, into a carbonate. It has been
accurately determined that one square decimetre receives in this way, a
coating of carbonate of lime which weighs 0·732 grammes. Upon the 105
square metres already mentioned there must accordingly be formed 7686
grammes of carbonate of lime, which contain 4325·6 grammes of carbonic
acid. The weight of one cubic decimetre of carbonic acid being calcu-
lat··d at two grammes, (more accurately 1·97978,) the above-mentioned
surface must absorb in four days 2·163 cubic metres of carbonic acid.
2500 square metres (one Hessian acre) would absorb, under a similar

But it is inconceivable, that the functions of the organs of a plant can cease for any one moment during its life. The roots and other parts of it, which possess the same power, absorb constantly water and carbonic acid. This power is independent of solar light. During the day, when the plants are in the shade, and during the night, carbonic acid is accumulated in all parts of their struc-ure; and the assimilation of the carbon and the exhalation of oxygen commence from the instant that the rays of the sun strike them. As soon as a young plant breaks through the surface of the ground, it begins to acquire colour from the top downwards; and the true formation of woody tissue commences at the same time.

The proper, constant, and inexhaustible sources of oxygen gas are the tropics and warm climates, where a sky, seldom clouded, permits the glowing rays of the sun to shine upon an immeasurably luxuriant vegetation. The temperate and cold zones, where artificial warmth must replace deficient heat of the sun, produce, on the contrary, carbonic acid in superabundance, which is expended in the nutrition of the tropical plants. The same stream of air, which moves by the revolution of the earth from the equator to the poles, brings to us, in its passage from the equator, the oxygen generated there, and carries away the carbonic acid formed during our winter.

The experiments of De Saussure have proved, that the upper strata of the air contain more carbonic acid than the lower, which are in contact with plants; and that the quantity is greater by night than by day, when it undergoes decomposition.

treatment, 51¼ cubic metres = 1818 cubic feet of carbonic acid in four days. In 200 days it would absorb 2575 cubic metres = 904,401 cubic feet, which contain 11,353 lbs. of carbonic acid, of which 3304 lbs. are carbon, a quantity three times as great as that which is assimilated by the leaves and roots growing upon the same space.

Plants thus improve the air, by the removal of carbonic acid, and by the renewal of oxygen, which is immediately applied to the use of man and animals. The horizontal currents of the atmosphere bring with them as much as they carry away, and the interchange of air between the upper and lower strata, which their difference of temperature causes, is extremely trifling when compared with the horizontal movements of the winds. Thus, vegetable culture heightens the healthy state of a country, and a previously healthy country would be rendered quite uninhabitable by the cessation of all cultivation.

The various layers of wood and mineral coal, as well as peat, form the remains of a primeval vegetation. The carbon which they contain must have been originally in the atmosphere as carbonic acid, in which form it was assimilated by the plants which constitute these formations. It follows from this, that the atmosphere must be richer in oxygen at the present time than in former periods of the earth's history. The increase must be exactly proportional to the quantity of carbon and hydrogen contained in these carboniferous deposits. Thus, during the formation of 353 cubic feet of Newcastle splint-coal, the atmosphere must have received 643 cubic feet of oxygen produced from the carbonic acid assimilated, and also 158 cubic feet of the same gas resulting from the decomposition of water. In former ages, therefore, the atmosphere must have contained less oxygen, but a much larger proportion of carbonic acid, than it does at the present time, a circumstance which accounts for the richness and luxuriance of the earlier vegetation.

But a certain period must have arrived in which the quantity of carbonic acid contained in the air experienced neither increase nor diminution in any appreciable quantity. For if it received an additional quantity to its usual

proportion, an increased vegetation would be the natural consequence, and the excess would thus be speedily removed. And, on the other hand, if the gas was less than the normal quantity, the progress of vegetation would be retarded, and the proportion would soon attain its proper standard.

The most important function in the life of plants, or, in other words, in their assimilation of carbon, is the separation, we might almost say the generation, of oxygen. 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 shown 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, and sugar, for they all contain the elements of woody fibre, and nearly in the same proportions.

In the second part of the work we shall adduce satisfactory proofs that decayed woody fibre (*humus*) contains carbon and the elements of water, without an excess of oxygen ; its composition differing from that of woody fibre in its being richer in carbon.

Misled by this simplicity in its constitution, physiologists found no difficulty in discovering the mode of the

formation of woody fibre; for they say*, humus has only
to enter into combination with water, in order to effect the
formation of woody fibre, and other substances similarly
composed, such as sugar, starch, and gum. But they
forget that their own experiments have sufficiently
demonstrated the inaptitude of these substances for
assimilation.

All the erroneous opinions concerning the *modus ope-
randi* of humus have their origin in the false notions
entertained respecting the most important vital functions
of plants; analogy, that fertile source of error, having,
unfortunately, led to the very unapt comparison of the
vital functions of plants with those of animals.

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 un-
healthy elms, oaks, and horse-chesnuts, 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 sustenance and vigour are ascribed?

How does it happen, it may be asked, that the absorp-
tion of carbon from the atmosphere by plants is doubted
by all botanists and vegetable physiologists, and that by
the greater number the purification of the air by means of
them is wholly denied?

The action of plants on the air in the absence of light,
that is during night, has been much misconceived by

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* Meyen, *Pflanzenphysiologie*, II. S. 141.

botanists, and from this we may trace most of the errors which abound in the greater part of their writings. The experiments of Ingenhouss were in a great degree the cause of this uncertainty of opinion regarding the influence of plants in purifying the air. His observation that green plants emit carbonic acid in the dark, led De Saussure and Grischow to new investigations, by which they ascertained that under such conditions plants do really absorb oxygen and emit carbonic acid; but that the whole volume of air undergoes diminution at the same time. From the latter fact it follows, that the quantity of oxygen gas absorbed is greater than the volume of carbonic acid separated; for, if this were not the case, no diminution could occur. These facts cannot be doubted, but the views based on them have been so false, that nothing except the total want of observation and the utmost ignorance of the chemical relations of plants to the atmosphere, can account for their adoption.

It is known that nitrogen, hydrogen, and a number of other gases, exercise a peculiar, and in general an injurious influence upon living plants. Is it, then, probable, that oxygen, one of the most energetic agents in nature, should remain without influence on plants when one of their peculiar processes of assimilation has ceased?

It is true that the decomposition of carbonic acid is arrested by absence of light. But then, namely, at night, a true chemical process commences, in consequence of the action of the oxygen in the air, upon the organic substances composing the leaves, blossoms, and fruit. This process is not at all connected with the life of the vegetable organism, because it goes on in a dead plant exactly as in a living one.

The substances composing the leaves of different

plants being known, it is a matter of the greatest ease
and certainty to calculate which of them, during life,
should absorb most oxygen by chemical action when the
influence of light is withdrawn.

The leaves and green parts of all plants containing
volatile oils or volatile constituents in general, which
change into resin by the absorption of oxygen, should
absorb more than other parts which are free from such
substances.   Those leaves, also, which contain either the
constituents of nut-galls, or compounds in which nitro-
gen is present, ought to absorb more oxygen than those
which do not contain such matters.   The correctness of
these inferences has been distinctly proved by the obser-
vations of De Saussure; for, whilst the tasteless leaves
of the *Agave americana* absorb only 0·3 of their volume
of oxygen in the dark, during 24 hours, the leaves of the
Pinus Abies, which contain volatile and resinous oils,
absorb 10 times those of the *Quercus Robur,* containing.
tannic acid 14 times, and the balmy leaves of the *Populus
alba* 21 times that quantity.   This chemical action is
shown very plainly also, in the leaves of the *Cotyledon
calycinum,* the *Cacalia ficoides,* and others; for they are
sour like sorrel in the morning, tasteless at noon, and
bitter in the evening.   The formation of acids is effected
during the night by a true process of oxidation: these
are deprived of their acid properties during the day and
evening, and are changed by separation of a part of their
oxygen into compounds containing oxygen and hydrogen,
either in the same proportions as in water, or even with
an excess of hydrogen, which is the composition of all
tasteless and bitter substances.

Indeed the quantity of oxygen absorbed could be esti-
mated pretty nearly bv the different periods. which the

green leaves of plants require to undergo alteration in colour, by the influence of the atmosphere. Those which continue longest green will abstract less oxygen from the air in an equal space of time, than those the constituent parts of which suffer a more rapid change. It is found, for example, that the leaves of the *Ilex aquifolium*, distinguished by the durability of their colour, absorb only 0·86 of their volume of oxygen gas in the same time that the leaves of the poplar absorb 8, and those of the beech $9\frac{1}{2}$ times their volume ; both the beech and poplar being remarkable for the rapidity and ease with which the colour of their leaves changes.

When the green leaves of the poplar, the beech, the oak, or the holly, are dried under the air-pump, with exclusion of light, then moistened with water, and placed under a glass globe filled with oxygen, they are found to absorb that gas in proportion as they change in colour. The chemical nature of this process is thus completely established. The diminution of the gas which occurs can only be owing to the union of a large proportion of oxygen with those substances which are already in the state of oxides, or to the oxidation of the hydrogen in those vegetable compounds which contain it in excess. The fallen brown or yellow leaves of the oak contain no longer tannin, and those of the poplar no balsamic constituents.

The property which green leaves possess of absorbing oxygen belongs also to fresh wood, whether taken from a twig or from the interior of the trunk of a tree. When fine chips of such wood are placed in a moist condition under a jar filled with oxygen, the gas is seen to diminish in volume. But wood, dried by exposure to the atmosphere, and then moistened, converts the oxygen into

carbonic acid, without change of volume; fresh wood,
therefore, absorbs most oxygen.

MM. Petersen and Schödler have shown, by the care-
ful elementary analysis of 24 different kinds of wood,
that they contain carbon and the elements of water, with
the addition of a certain quantity of hydrogen. Oak
wood, recently taken from the tree, and dried at 100° C.
(212° F.), contains 49.432 carbon, 6.069 hydrogen, and
44.499 oxygen.

The proportion of hydrogen which is necessary to
combine with 44.498 oxygen in order to form water, is
$\frac{1}{8}$ of this quantity, namely, 5.56; it is evident, therefore,
that oak wood contains $\frac{1}{12}$ more hydrogen than corre-
sponds to this proportion. In *Pinus Larix*, *P. Abies*,
and *P. picea*, the excess of hydrogen amounts to $\frac{1}{4}$, and
in *Tilia europæa* to $\frac{1}{5}$. The quantity of hydrogen stands
in some relation to the specific weight of the wood; the
lighter kinds of wood contain more of it than the heavier.
In ebony wood (*Diospyros Ebenum*) the oxygen and
hydrogen are in exactly the same proportion as in water.

The difference between the composition of the varieties
of wood, and that of simple woody fibre, depends, un-
questionably, upon the presence of constituents, in part
soluble, and in part insoluble, such as resin and other
matters, which contain a large proportion of hydrogen :
the hydrogen of such substances being in the analysis of
the various woods superadded to that of the true woody
fibre.

It has previously been mentioned that mouldering oak
wood contains carbon and the elements of water, without
any excess of hydrogen. But the proportions of its con-
stituents must necessarily have been different, if the
volume of the air had not changed during its decay,

because the proportion of hydrogen in those component substances' of the wood which contained it in excess is here diminished, and this diminution could only be effected by an absorption of oxygen, and consequent formation of water.

Most vegetable physiologists have connected the emission of carbonic acid during the night with the absorption of oxygen from the atmosphere, and have considered these actions as a true process of respiration in plants, similar to that of animals, and like it, having for its result the separation of carbon from some of their constituents. This opinion has a very weak and unstable foundation.

The carbonic acid, which has been absorbed by the leaves and by the roots, together with water, ceases to be decomposed on the departure of day-light; it is dissolved in the juices which pervade all parts of the plant, and escapes every moment through the leaves in quantity corresponding to that of the water which evaporates.

A soil in which plants vegetate vigorously, contains a certain quantity of moisture which is indispensably necessary to their existence. Carbonic acid, likewise, is always present in such a soil, whether it has been abstracted from the air or has been generated by the decay of vegetable matter. Rain and well water, and also that from other sources, invariably contains carbonic acid.— Plants during their life constantly possess the power of absorbing by their roots moisture, and, along with it, air and carbonic acid. Is it, therefore, surprising that the carbonic acid should be returned unchanged to the atmosphere, along with water, when light (the cause of the fixation of its carbon) is absent?

Neither this emission of carbonic acid nor the absorption of oxygen has any connexion with the process of

assimilation; nor have they the slightest relation to one another; the one is a purely mechanical, the other a purely chemical process. A cotton wick, inclosed in a lamp, which contains a liquid saturated with carbonic acid, acts exactly in the same manner as a living plant in the night. Water and carbonic acid are sucked up by capillary attraction, and both evaporate from the exterior part of the wick.

Plants which live in a soil containing humus exhale much more carbonic acid during the night than those which grow in dry situations; they also yield more in rainy than in dry weather. These facts point out to us the cause of the numerous contradictory observations, which have been made with respect to the change impressed upon the air by living plants, both in darkness and in common day-light, but which are unworthy of consideration, as they do not assist in the solution of the main question.

There are other facts which prove in a decisive manner that plants yield more oxygen to the atmosphere than they extract from it; these proofs, however, are to be drawn with certainty only from plants which live under water.

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. These 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 this oxygen is the
carbonic acid dissolved in the water, which is absorbed
by the plants, but is again supplied to 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 aerial plants upon the atmosphere is very easily
explained.

The opinion is not new that the carbonic acid of the
air serves for the nutriment of plants, and that its carbon
is assimilated by them ; it has been admitted, defended,
and argued for, by the soundest and most intelligent
natural philosophers, namely, by Priestley, Sennebier,
De Saussure, and even by Ingenhouss himself. There
scarcely exists a theory in natural science, in favour of
which there are more clear and decisive arguments. How,
then, are we to account for its not being received in its
full extent by most other physiologists, for its being
even disputed by many, and considered by a few as
quite refuted?

All this is due to two causes, which we shall now
consider.

One is, that in botany the talent and labour of inquirers
has been wholly spent in the examination of form and
structure : chemistry and physics have not been allowed
to sit in council upon the explanation of the most simple
processes ; their experience and their laws have not been
employed, though the most powerful means of help in the

acquirement of true knowledge. They have not been used, because their study has been neglected.

All discoveries in physics and in chemistry, all explanations of chemists, must remain without fruit and useless, because, even to the great leaders in physiology, carbonic acid, ammonia, acids, and bases, are sounds without meaning, words without sense, terms of an unknown language, which awaken no thoughts and no associations. They treat these sciences like the vulgar, who despise a foreign literature in exact proportion to their ignorance of it; since even when they have had some acquaintance with them, they have not understood their spirit and application.

Physiologists reject the aid of chemistry in their inquiry into the secrets of vitality, although it alone could guide them in the true path; they reject chemistry, because in its pursuit of knowledge it destroys the subjects of its investigation; but they forget that the knife of the anatomist must dismember the body, and destroy its organs, if an account is to be given of their form, structure, and functions.

When pure potato starch is dissolved in nitric acid, a ring of the finest wax remains. What can be opposed to the conclusion of the chemist, that each grain of starch consists of concentric layers of wax and amylin, which thus mutually protect each other against the action of water and ether? Can results of this kind, which illustrate so completely both the nature and properties of bodies, be attained by the microscope? Is it possible to make the gluten in a piece of bread visible in all its connexions and ramifications? It is impossible by means of instruments; but if the piece of bread is placed in a lukewarm decoction of malt, the starch, and the substance

called dextrine*, are seen to dissolve like sugar in water, and, at last, nothing remains except the gluten, in the form of a spongy mass, the minute pores of which can be seen only by a microscope.

Chemistry offers innumerable resources of this kind which are of the greatest use in an inquiry into the nature of the organs of plants; but they are not used, because the need of them is not felt. The most important organs of animals and their functions are known, although they may not be visible to the naked eye. But in vegetable physiology, a leaf is in every case regarded merely as a leaf, notwithstanding that leaves generating oil of turpentine or oil of lemons must possess a different nature from those in which oxalic acid is formed. Vitality, in its peculiar operations, makes use of a special apparatus for each function of an organ. A rose-twig engrafted upon a lemon-tree does not bring forth lemons, but roses. Vegetable physiologists in the study of their science have not directed their attention to that part of it which is most worthy of investigation.

The second cause of the incredulity with which physiologists view the theory of the nutrition of plants by the carbonic acid of the atmosphere is, that the art of experimenting is not known in physiology, it being an art which can be learned accurately only in the chemical laboratory. Nature speaks to us in a peculiar language, in the language of phenomena; she answers at all times the questions which are put to her; and such questions

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* According to Raspail, starch consists of vesicles inclosing within them a fluid resembling gum. Starch may be put in cold water without being dissolved; but, when placed in hot water, these spherules burst, and allow the escape of the liquid. This liquid is the *dextrine* of Biot, so called because it possesses the property of turning the plane of the polarisation of light to the right hand.—ED.

are experiments.   An experiment is the expression
of a thought: we are near the truth when the pheno-
menon elicited by the experiment corresponds to the
thought; while the opposite result shows that the
question was falsely stated, and that the conception was
erroneous.

The critical repetition of another's experiments must be
viewed as a criticism of his opinions; if the result of the
criticism be merely negative, if it do not suggest more
correct ideas in the place of those which it is intended to
refute, it should be disregarded; because the worse expe-
rimenter the critic is, the greater will be the discrepancy
between the results he obtains and the views proposed
by the other.

It is too much forgotten by physiologists, that their
duty really is not to refute the experiments of others, nor
to show that they are erroneous, but to discover truth, and
that alone.   It is startling, when we reflect that all the
time and energy of a multitude of persons of genius,
talent, and knowledge, are expended in endeavours to
demonstrate each other's errors.

The question whether carbonic acid is the food of
plants or not, has been made the subject of experiments
with perfect zeal and good faith; the results have
been opposed to that view.   But how was the inquiry
instituted?

The seeds of balsamines, beans, cresses, and gourds,
were sown in pure Carrara marble, and sprinkled with
water containing carbonic acid.   The seeds sprang, but
the plants did not attain to the development of the third
small leaf.   In other cases, they allowed the water to
penetrate the marble from below, yet, in spite of this,
they died.   It is worthy of observation, that they lived

longer with pure distilled water than with that impregnated with carbonic acid; but still, in this case also, they eventually perished. Other experimenters sowed seeds of plants in flowers of sulphur and sulphate of barytes, and tried to nourish them with carbonic acid, but without success.

Such experiments have been considered as positive proofs that carbonic acid will not nourish plants; but the manner in which they were instituted is opposed to all rules of philosophical inquiry and to all the laws of chemistry.

Many conditions are necessary for the life of plants; those of each genus require special conditions; and should but one of these be wanting, although the rest be supplied, the plants will not be brought to maturity. The organs of a plant, as well as those of an animal, contain substances *of the most different kinds; some are formed solely of* carbon and the elements of water, others contain nitrogen, and in all plants we find metallic oxides in the state of salts. The food which can serve for the production of all the organs of a plant, must necessarily contain all its elements. These most essential of all the chemical qualities of nutriment may be united in one substance, or they may exist separately in several; in which case, the one contains what is wanting in the other. Dogs die although fed with jelly, a substance which contains nitrogen; they cannot live upon white bread, sugar, or starch, if these are given as food, to the exclusion of all other substances. Can it be concluded from this, that these substances contain no elements suited for assimilation? Certainly not.

Vitality is the power which each organ possesses of constantly reproducing itself; for this it requires a supply of

substances which contain the constituent elements of its own substance, and are capable of undergoing transformation. All the organs together cannot generate a single element, carbon, nitrogen, or a metallic oxide.

When the quantity of the food is too great, or is not capable of undergoing the necessary transformation, or exerts any peculiar chemical action, the organ itself is subjected to a change; all poisons act in this manner. The most nutritious substances may cause death. In experiments such as those described above, every condition of nutrition should be considered. Besides those matters which form their principal constituent parts, both animals and plants require others, the peculiar functions of which are unknown. These are inorganic substances, such as common salt, the total want of which is in animals inevitably productive of death. Plants, for the same reason, cannot live unless supplied with certain metallic compounds.

If we knew with certainty that there existed a substance capable, alone, of nourishing a plant and of bringing it to maturity, we might be led to a knowledge of the conditions necessary to the life of all plants, by studying its characters and composition. If humus were such a substance, it would have precisely the same value as the only single food which nature has produced for animal organization, namely, milk (Prout). The constituents of milk are cheese or caseine, a compound containing nitrogen in large proportion; butter, in which hydrogen abounds; and sugar of milk, a substance with a large quantity of hydrogen and oxygen in the same proportion as in water. It also contains in solution, lactate of soda, phosphate of lime, and common salt; and a peculiar aromatic product exists in the butter, called butyric acid.

The knowledge of the composition of milk is a key to the conditions necessary for the purposes of nutrition of all animals.

All substances which are adequate to the nourishment of animals contain those materials united, though not always in the same form; nor can any one be wanting for a certain space of time, without a marked effect on the health being produced. The employment of a substance as food presupposes a knowledge of its capacity of assimilation, and of the conditions under which this takes place.

A carnivorous animal dies in the vacuum of an air-pump, even though supplied with a superabundance of food; it dies in the air, if the demands of its stomach are not satisfied; and it dies in pure oxygen gas, however lavishly nourishment be given to it. Is it hence to be concluded, that neither flesh, nor air, nor oxygen, is fitted to support life? Certainly not.

From the pedestal of the Trajan column at Rome we might chisel out each single piece of stone, if upon the extraction of the second we replaced the first. But could we conclude from this that the column was suspended in the air, and not supported by a single piece of its foundation? Assuredly not. Yet the strongest proof would have been given that each portion of the pedestal could be removed, without the downfall of the column.

Animal and vegetable physiologists, however, come to such conclusions with respect to the process of assimilation. They institute experiments, without being acquainted with the circumstances necessary for the continuance of life—with the qualities and proper nutriment of the animal or plant on which they operate—or with the nature and chemical constitution of its organs. These

experiments are considered by them as convincing proofs, whilst they are fitted only to awaken pity.

Is it possible to bring a plant to maturity by means of carbonic acid and water, without the aid of some substance containing nitrogen, which is an essential constituent of the sap, and indispensable for its production ? Must the plant not die, however abundant the supply of carbonic acid may be, as soon as the first small leaves have exhausted the nitrogen contained in the seeds ?

Can a plant be expected to grow in Carrara marble, even when an azotised substance is supplied to it, if the marble be sprinkled with an aqueous solution of carbonie acid, which dissolves the lime and forms bicarbonate of lime ? A plant of the family of the *Plumbagineæ*, upon the leaves of which fine hornlike, or scaly processes of crystallised carbonate of lime are formed, might perhaps attain maturity under such circumstances; but these experiments are only sufficient to prove, that cresses, gourds, and balsamines, cannot be nourished by bicarbonate of lime, in the absence of matter containing nitrogen. We may, indeed, conclude, that the salt of lime acts as a poison, since the development of plants will advance further in pure water, when lime and carbonic acid are not used.

Moist flowers of sulphur attract oxygen from the atmosphere, and become acid. Is it possible that a plant can grow and flourish in presence of free sulphuric acid, with no other nourishment than carbonic acid ? It is true, the quantity of sulphuric acid formed thus in hours, or in days, may be small; but the property of each particle of the sulphur to absorb oxygen and retain it, is present every moment.

When it is known that plants require moisture, car-

bonic acid, and air, should we choose, as the soil for experiments on their growth, sulphate of barytes, which, from its nature and specific gravity, completely prevents the access of air ?

All these experiments are valueless for the decision of any question. It is absurd to take for them any soil, at mere hazard, as long as we are ignorant of the functions performed in plants by those inorganic substances which are apparently foreign to them. It is quite impossible to mature a plant of the family of the *Graminea*, or of the *Equisetaceæ*, the solid framework of which contains silicate of potash, without silicic acid and potash, or a plant of the genus *Oxalis* without potash, or saline plants such as the saltworts (*Salsola* and *Salicornia*) without chloride of sodium, or at least some salt of similar properties. All seeds of the *Gramineæ* contain phosphate of magnesia ; the solid parts of the roots of the *Althœa* contain more phosphate of lime than woody fibre. Are these substances merely accidentally present ? A plant should not be chosen for experiment, when the matter which it requires for its assimilation is not well known.

What value, now, can be attached to experiments in which all those matters which a plant requires in the process of assimilation, besides its mere nutriment, have been excluded with the greatest care ? Can the laws of life be investigated in an organised being which is diseased or dying ?

The mere observation of a wood or meadow is infinitely better adapted to decide so simple a question than all the trivial experiments under a glass globe; the only difference is that instead of one plant there are thousands. When we are acquainted with the nature of a single

cubic inch of their soil, and know the composition of the
air and rain-water, we are in possession of all the condi-
tions necessary to their life.   The source of the different
elements entering into the composition of plants cannot
possibly escape us, if we know in what form they take up
their nourishment, and compare its composition with
that of the vegetable substances which compose their
structure.

All these questions will now be examined and dis-
cussed.   It has been already shown that the carbon of
plants is derived from the atmosphere : it still remains
for us to inquire what power is exerted on vegetation
by the humus of the soil and the inorganic consti-
tuents of plants, and also to trace the sources of their
nitrogen.

CHAPTER III.

ON THE ORIGIN AND ACTION OF HUMUS.

It will be shown in the second part of this work, that all plants and vegetable structures undergo two processes of decomposition after death. One of these is named *fermentation;* the other, *putrefaction, decay,* or *eremacausis**.

It will likewise be shown, that decay is a slow process of combustion,—a process, therefore, in which the combustible parts of a plant unite with the oxygen of the atmosphere.

The decay of woody fibre (the principal constituent of all plants) is accompanied by a phenomenon of a peculiar kind. This substance, in contact with air or oxygen gas, converts the latter into an equal volume of carbonic acid, and its decay ceases upon the disappearance of the oxygen. If the carbonic acid is removed, and oxygen replaced, its decay recommences, that is, it again converts oxygen into carbonic acid. Woody fibre consists of carbon and the elements of water; and if we judge only from the products formed during its decomposition, and from those formed by pure charcoal, burned at a high temperature, we might conclude that the causes were the same in both : the decay of woody fibre proceeds, there-

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* The word *eremacausis* was proposed by the author some time since, in order to explain the true nature of decay ; it is compounded from ἠρέμα *by degrees*, and καῦσις *burning*.

fore, as if no hydrogen or oxygen entered into its com-
position.

A very long time is required for the completion of this
process of combustion, and the presence of water is neces-
sary for its maintenance : alkalies promote it, but acids
retard it; all antiseptic substances, such as sulphurous
acid, the mercurial salts, empyreumatic oils, &c., cause
its complete cessation.

Woody fibre in a state of decay is the substance called
humus *.

The property of woody fibre to convert surrounding
oxygen gas into carbonic acid diminishes in proportion
as its decay advances, and at last a certain quantity of a
brown coaly-looking substance remains, in which this
property is entirely wanting.   This substance is called
mould ; it is the product of the complete decay of woody
fibre.   Mould constitutes the principal part of all the
strata of brown coal and peat.

Humus acts in the same manner in a soil permeable to
air as in the air itself; it is a continued source of car-
bonic acid, which it emits very slowly.   An atmosphere
of carbonic acid, formed at the expense of the oxygen
of the air, surrounds every particle of decaying humus.
The cultivation of land, by tilling and loosening the soil,
causes a free and unobstructed access of air.   An atmo-
sphere of carbonic acid is therefore contained in every
fertile soil, and is the first and most important food for
the young plants which grow in it.

In spring, when those organs of plants are absent
which nature has appointed for the assumption of nou-

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* The humic acid of chemists is a product of the decomposition of
humus by alkalies ; it does not exist in the humus of vegetable physiolo-
gists.

rishment from the atmosphere, the component substance of the seeds is exclusively employed in the formation of the roots. Each new radicle fibril which a plant acquires may be regarded as constituting at the same time a mouth, a lung, and a stomach. The roots perform the functions of the leaves from the first moment of their formation: they extract from the soil their proper nutriment, namely, the carbonic acid generated by the humus.

By loosening the soil which surrounds young plants, we favour the access of air, and the formation of carbonic acid: and, on the other hand, the quantity of their food is diminished by every difficulty which opposes the renewal of air. A plant itself effects this change of air at a certain period of its growth. The carbonic acid, which protects the undecayed humus from further change, is absorbed and taken away by the fine fibres of the roots, and by the roots themselves: this is replaced by atmospheric air, by which process the decay is renewed, and a fresh portion of carbonic acid formed. A plant at this times receives its food both by the roots and by the organs above ground, and advances rapidly to maturity.

When a plant is quite matured, and when the organs by which it obtains food from the atmosphere are formed, the carbonic acid of the soil is no further required.

Deficiency of moisture in the soil, or its complete dryness, does not now check the growth of a plant, provided it receives from the dew and the atmosphere as much as is requisite for the process of assimilation. During the heat of summer it derives its carbon exclusively from the atmosphere.

We do not know what height and strength nature has allotted to plants; we are acquainted only with the size which they usually attain. Oaks are shown, both in

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We do not know what height and strength nature has
allotted to plants ; we are acquainted only with the size
which they usually attain.   Oaks are shown, both in

London and Amsterdam, as remarkable curiosities, which have been reared by Chinese gardeners, and are only one foot and a half in height, although their trunks, barks, leaves, branches, and whole habitus, evince a venerable age. The small parsnep grown at Teltow*, when placed in a soil which yields as much nourishment as it can take up, increases to several pounds in weight.

The size of a plant is proportional to the surface of the organs which are destined to convey food to it. A plant gains another mouth and stomach with every new fibre of root, and every new leaf.

The power which roots possess of taking up nourishment does not cease as long as nutriment is present. When the food of a plant is in greater quantity than its organs require for their own perfect development, the superfluous nutriment is not returned to the soil, but is employed in the formation of new organs. At the side of a cell, already formed, another cell arises; at the side of a twig and leaf, a new twig and a new leaf are developed. These new parts could not have been formed had there not been an excess of nourishment. The sugar and mucilage produced in the seeds, form the nutriment of the young plants, and disappear during the development of the buds, green sprouts, and leaves.

The power of absorbing nutriment from the atmosphere, with which the leaves of plants are endowed, being proportionate to the extent of their surface, every increase in the size and number of these parts is necessarily attended with an increase of nutritive power, and a consequent further development of new leaves and branches.

* Teltow is a village near Berlin, where small parsneps are cultivated in a sandy soil; they are much esteemed, and weigh rarely above one ounce.

Leaves, twigs, and branches, when completely matured, as they do not become larger, do not need food for their support. . For their existence as organs, they require only the means necessary for the performance of the special functions to which they are destined by nature ; they do not exist on their own account.

We know that the functions of the leaves and other green parts of plants are to absorb carbonic acid, and with the aid of light and moisture, to appropriate its carbon. These processes are continually in operation ; they commence with the first formation of the leaves, and do not cease with their perfect development. But the new products arising from this continued assimilation are no longer employed by the perfect leaves in their own increase : they serve for the formation of woody fibre, and all the solid matters of similar composition. The leaves now produce sugar, amylin or starch, and acids, which were previously formed by the roots when they were necessary for the development of the stem, buds, leaves, and branches of the plant.

The organs of assimilation, at this period of their life, receive more nourishment from the atmosphere than they employ in their own sustenance ; and when the formation of the woody substance has advanced to a certain extent, the expenditure of the nutriment, the supply of which still remains the same, takes a new direction, and blossoms are produced. The functions of the leaves of most plants cease upon the ripening of their fruit, because the products of their action are no longer needed. They now yield to the chemical influence of the oxygen of the air, generally suffer a change in colour, and fall off.

A peculiar " transformation " of the matters contained in all plants takes place in the period between blossom-

ing and the ripening of the fruit; new compounds are produced, which furnish constituents of the blossoms, fruit, and seed.   An organic chemical " transformation" is the separation of the elements of one or several combinations, and their reunion into two or several others, which contain the same number of elements, either grouped in another manner, or in different proportions. Of two compounds formed in consequence of such a change, one remains as a component part of the blossom or fruit, while the other is separated by the roots in the form of excrementitious matter.   No process of nutrition can be conceived to subsist in animals or vegetables, without a separation of effete matters.   We know, indeed, that an organized body cannot generate substances, but can only change the mode of their combination, and that its sustenance and reproduction depend upon the chemical transformation of the matters which are employed as its nutriment, and which contain its own constituent elements.

Whatever we regard as the cause of these transformations, whether the Vital Principle, Increase of Temperature, Light, Galvanism, or any other influence, the act of transformation is a purely chemical process.   Combination and Decomposition can take place only when the elements are disposed to these changes.   That which chemists name *affinity* indicates only the degree in which they possess this disposition.   It will be shown, when considering the processes of fermentation and putrefaction, that every disturbance of the mutual attraction subsisting between the elements of a body gives rise to a transformation.   The elements arrange themselves according to the degrees of their reciprocal attraction into new combinations, which are incapable of further change under the same conditions.

The products of these transformations vary with their causes, that is, with the different conditions on which their production depended ; and are as innumerable as these conditions themselves. The chemical character of an acid, for example, is its unceasing disposition to saturation by means of a base ; this disposition differs in intensity in different acids ; but when it is satisfied, the acid character entirely disappears. The chemical character of a base is exactly the reverse of this, but both an acid and a base, notwithstanding the great difference in their properties, effect, in most cases, the same kind of transformations.

Hydrocyanic acid and water contain the elements of *carbonic acid, ammonia, urea, cyanuric acid, cyanilic acid, oxalic acid, formic acid, melam, ammelin, melamin, azulmin, mellon, hydromellonic acid, allantoin, &c.* It is well known, that all these very different substances can be obtained from hydrocyanic acid and the elements of water, by various chemical transformations.

The whole process of nutrition may be understood by the consideration of one of these transformations.

Hydrocyanic acid and water, for example, when brought into contact with muriatic acid, are decomposed into formic acid and ammonia ; both of these products of decomposition contain the elements of hydrocyanic acid and water, although in another form, and arranged in a different order. The change results from the strong disposition or struggle of muriatic acid to undergo saturation, in consequence of which the hydrocyanic acid and water suffer mutual decomposition. The nitrogen of the hydrocyanic acid and the hydrogen of the water unite together, and form a base, ammonia, with which the acid unites ; the chemical characters of the acid being at the

All superabundant nitrogen is eliminated from the body, as a liquid excrement, through the urinary passages; all solid substances, incapable of further transformation, pass out by the intestinal canal, and all gaseous matter by the lungs.

We should not permit ourselves to be withheld by the idea of a *vital principle*, from considering in a chemical point of view the process of the transformation of the food, and its assimilation by the various organs. This is the more necessary, as the views, hitherto held, have produced no results, and are quite incapable of useful application.

Is it truly vitality, which generates sugar in the germ for the nutrition of young plants, or which gives to the stomach the power to dissolve, and to prepare for assimilation, all the matter introduced into it? A decoction of malt possesses as little power to reproduce itself, as the stomach of a dead calf; both are, unquestionably, destitute of life. But when amylin or starch is introduced into a decoction of malt, it changes, first into a gummy-like matter, and lastly into sugar. Hard-boiled albumen and muscular fibre can be dissolved in a decoction of a calf's stomach, to which a few drops of muriatic acid have been added, precisely as in the stomach itself.* (Schwann, Schulz.)

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of the various substances contained in the blood. It certainly well merits consideration, that the most approved remedies for counteracting or stopping the progress of this frightful malady are precisely those which are found most efficacious in retarding putrefaction. Thus, it is well known that much relief is afforded by a residence in works in which empyreumatic oils are manufactured by dry distillation, such as manufactories for the preparation of gas or sal-ammoniac. For the same reason, the respiration of wood vinegar (pyroligneous acid), of chlorine, and certain of the acids, has been recognised as a means of alleviating the disease.

* This remarkable action has been completely confirmed in this laboratory (Giessen), by Dr. Vogel, a highly distinguished young physiologist.

The power, therefore, to effect transformations, does not belong to the vital principle : each transformation is owing to a disturbance in the attraction of the elements of a compound, and is consequently a purely chemical process. There is no doubt that this process takes place in another form from that of the ordinary decomposition of salts, oxides, or sulphurets. But is it the fault of chemistry that physiology has hitherto taken no notice of this new form of chemical action?

Physicians are accustomed to administer whole ounces of borax to patients suffering under urinary calculi, when it is known that the bases of all alkaline salts formed by organic acids are carried through the urinary passages in the form of alkaline carbonates, capable of dissolving calculi (Wöhler). Is this rational ? The medical reports state, that upon the Rhine, where so much cream of tartar is consumed in wine, the only cases of calculous disorders are those which are imported from other districts. We know that the uric acid calculus is transformed into the mulberry calculus (which contains oxalic acid), when patients suffering under the former exchange the town for the country, where less animal and more vegetable food is used. Are all these circumstances incapable of explanation ?

The volatile oil of the roots of valerian may be obtained from the oil generated during the fermentation of potatoes (Dumas), and the oil of the *Spiræa ulmaria* from the crystalline matter of the bark of the willow (Piria). We are able to form in our laboratories formic acid, oxalic acid, urea, and the crystalline substances existing in the liquid of the allantois of the cow, all products, it is said, of the vital principle. We see, therefore, that this mysterious principle has many relations in common with

chemical forces, and that the latter can indeed replace it. What these relations are, it remains for physiologists to investigate. Truly it would be extraordinary if this vital principle, which uses everything for its own purposes, had allotted no share to chemical forces, which stand so freely at its disposal. We shall obtain that which is obtainable in a rational inquiry into nature, if we separate the actions belonging to chemical powers from those which are subordinate to other influences. But the expression "vital principle" must in the mean time be considered as of equal value with the terms *specific* or *dynamic* in medicine: everything is specific which we cannot explain, and dynamic is the explanation of all which we do not understand; the terms having been invented merely for the purpose of concealing ignorance by the application of learned epithets.

Transformations of existing compounds are constantly taking place during the whole life of a plant, in consequence of which, and as the results of these transformations, there are produced gaseous matters which are excreted by the leaves and blossoms, solid excrements deposited in the bark, and fluid soluble substances which are eliminated by the roots. Such secretions are most abundant immediately before the formation and during the continuance of the blossoms ; they diminish after the development of the fruit. Substances containing a large proportion of carbon are excreted by the roots and absorbed by the soil. Through the expulsion of these matters unfitted for nutrition, the soil receives again with usury the carbon which it had at first yielded to the young plants as food, in the form of carbonic acid.

The soluble matter thus acquired by the soil is still capable of decay and putrefaction, and by undergoing

these processes furnishes renewed sources of nutrition to another generation of plants; it becomes *humus*. The cultivated soil is thus placed in a situation exactly analogous to that of forests and meadows; for the leaves of trees which fall in the forest in autumn, and the old roots of grass in the meadow, are likewise converted into humus by the same influence: a soil receives more carbon in this form than its decaying humus had lost as carbonic acid.

Plants do not exhaust the carbon of a soil in the normal condition of their growth; on the contrary, they add to its quantity. But if it is true that plants give back more carbon to a soil than they take from it, it is evident that their growth must depend upon the reception of nourishment from the atmosphere in the form of carbonic acid. The influence of humus upon vegetation is explained by the foregoing facts in the most clear and satisfactory manner.

Humus does not nourish plants by being taken up and assimilated in its unaltered state, but by presenting a slow and lasting source of carbonic acid, which is absorbed by the roots, and is the principal nutriment of young plants at a time when, being destitute of leaves, they are unable to extract food from the atmosphere.

In former periods of the earth's history, its surface was covered with plants, the remains of which are still found in the coal formations. These plants—the gigantic monocotyledons, ferns, palms, and reeds—belong to a class to which nature has given the power, by means of an immense extension of their leaves, to dispense with nourishment from the soil. They resemble in this respect the plants which we raise from bulbs and tubers, and which live while young upon the substances contained

in their seed, and require no food from the soil when their
exterior organs of nutrition are formed. This class of
plants is even at present ranked amongst those which do
not exhaust the soil.

The necessity of the existence of plants such as
these at the commencement of vegetation, must now be
apparent. Humus is a product of the decay of vegetable
matter, and therefore could not have existed to supply
the first plants with the food necessary for the develop-
ment of the more delicate kinds. Hence the plants capa-
ble of flourishing under such circumstances could only be
those which receive their nourishment from the air alone.
By their decay, however, the soil in which they grew
became supplied with vegetable matter, and the progress
of vegetation must have furnished to the earth materials
adapted for the development of those plants, which
depend upon the nutriment contained in the soil, until
those organs are formed which are destined for the
assumption of nourishment from the atmosphere.

The plants of every former period are distinguished
from those of the present by the inconsiderable develop-
ment of their roots. Fruit, leaves, seeds, nearly every
part of the plants of a former world, except the roots,
are found in the brown coal formation. The vascular
bundles, and the perishable cellular tissue, of which their
roots consisted, have been the first to suffer decomposi-
tion. But when we examine oaks and other trees, which
in consequence of revolutions of the same kind occurring
in later ages have undergone the same changes, we never
find their roots absent.

The verdant plants of warm climates are very often
such as obtain from the soil only a point of attachment,
and are not dependent on it for their growth. How

extremely small are the roots of the *Cactus, Sedum,* and *Sempervivum,* in proportion to their mass, and to the surface of their leaves! Large forests are often found growing in soils absolutely destitute of carbonaceous matter; and the extensive prairies of the Western Continent show that the carbon necessary for the sustenance of a plant may be entirely extracted from the atmosphere. Again, in the most dry and barren sand, where it is impossible for nourishment to be obtained through the roots, we see the milky-juiced plants attain complete perfection. The moisture necessary for the nutrition of these plants is derived from the atmosphere, and when assimilated is secured from evaporation by the nature of the juice itself. Caoutchouc and wax, which are formed in these plants, surround the water, as in oily emulsions, with an impenetrable envelope by which the fluid is retained, in the same manner as milk is prevented from evaporating by the skin which forms upon it. These plants, therefore, become turgid with their juices.

Particular examples might be cited of plants, which have been brought to maturity, upon a small scale, without the assistance of mould; but fresh proofs of the accuracy of our theory respecting the origin of carbon would be superfluous and useless, and could not render more striking, or more convincing, the arguments already adduced. It must not, however, be left unmentioned, that common wood charcoal, by virtue merely of its ordinary well-known properties, can completely replace vegetable mould or *humus.* The experiments of Lukas, which are appended to this work, spare me all further remarks upon its efficacy.

Plants thrive in powdered charcoal, and may be brought to blossom and bear fruit if exposed to the influence of

the rain and the atmosphere; the charcoal may be previously heated to redness.   Charcoal is the most "indifferent" and most unchangeable substance known; it may be kept for centuries without change, and is therefore not subject to decomposition. The only substances which it can yield to plants are some salts, which it contains, amongst which is silicate of potash.   It is known, however, to possess the power of condensing gases within its pores, and particularly carbonic acid.   And it is by virtue of this power that the roots of plants are supplied in charcoal, exactly as in humus, with an atmosphere of carbonic acid and air, which is renewed as quickly as it is abstracted.

In charcoal powder, which had been used for this purpose by Lukas for several years, Buchner found a brown substance soluble in alkalies. This substance was evidently due to the secretions from the roots of the plants which grew in it.

A plant placed in a closed vessel in which the air, and therefore the carbonic acid, cannot be renewed, dies exactly as it would do in the vacuum of an air-pump, or in an atmosphere of nitrogen or carbonic acid, even though its roots be fixed in the richest mould.

Plants do not, however, attain maturity, under ordinary circumstances, in charcoal powder, when they are moistened with pure distilled water instead of rain or river water.   Rain water must, therefore, contain within it one of the essentials of vegetable life; and it will be shown, that this is the presence of a compound containing nitrogen, the exclusion of which entirely deprives humus and charcoal of their influence upon vegetation.

CHAPTER IV.

ON THE ASSIMILATION OF HYDROGEN.

THE atmosphere contains the principal food of plants in the form of carbonic acid, in the state, therefore, of an oxide. The solid part of plants (woody fibre) contains carbon and the constituents of water, or the elements of carbonic acid, together with a certain quantity of hydrogen. It has formerly been mentioned that water consists of the two gases, oxygen and hydrogen. The range of affinity possessed by both these elements is so extensive that numerous causes occur which effect the decomposition of water. Indeed, there is no compound which plays a more general or more important part in the phenomena of combination and decomposition. We can conceive the wood to arise from a combination of the carbon of the carbonic acid with the elements of water, under the influence of solar light. In this case, 72·35 parts of oxygen, by weight, must be separated as a gas for every 27·65 parts of carbon which are assimilated by a plant; for this is the composition of carbonic acid in 100 parts. Or, what is much more probable, plants, under the same circumstances, may decompose water, the hydrogen of which is assimilated along with carbonic acid, whilst its oxygen is separated. If the latter change takes place, 8·04 parts of hydrogen must unite with 100 parts of carbonic acid, in order to form woody fibre, and the

72·35 parts by weight of oxygen, which was in combination with the hydrogen of the water, and which exactly corresponds in quantity with the oxygen contained in the carbonic acid, must be separated in a gaseous form.

Each acre of land, which produces 10 cwts. of carbon, gives annually to the atmosphere 865 lbs. of free oxygen gas. The specific weight of oxygen is expressed by the number 1·1026; hence 1 cubic metre of oxygen weighs 3·157 lbs., and 2865 lbs. of oxygen correspond to 908 cubic metres, or 32,007 cubic feet.

An acre of meadow, wood, or cultivated land in general replaces, therefore, in the atmosphere as much oxygen as is exhausted by 10 cwts. of carbon, either in its ordinary combustion in the air or in the respiratory process of animals.

It has been mentioned at a former page that pure woody fibre contains carbon and the component parts of water, but that ordinary wood contains more hydrogen than corresponds to this proportion. This excess is owing to the presence of the green principle of the leaf, wax, resin, and other bodies rich in hydrogen. Water must be decomposed, in order to furnish the excess of this element, and consequently one equivalent of oxygen must be given back to the atmosphere for every equivalent of hydrogen appropriated by a plant to the production of those substances. The quantity of oxygen thus set at liberty cannot be insignificant, for the atmosphere must receive 989 cubic feet of oxygen for every pound of hydrogen assimilated.

It has already been stated, that a plant, in the formation of woody fibre, must always yield to the atmosphere the same proportional quantity of oxygen; that the volume of this gas set free would be the same whether it were due

to the decomposition of carbonic acid or of water. A little consideration will show that this must be the case. It has repeatedly been stated, that woody fibre contains carbon in combination with oxygen and hydrogen in the same proportion in which they exist in water. Water contains 1 equivalent of each element, whilst carbonic acid consists of 1 equivalent of carbon, united to 2 equivalents of oxygen. In the formation of woody fibre, 2 equivalents of oxygen must therefore be liberated. The woody fibre can only be formed in one of two ways : either the carbon of carbonic acid unites directly with water, or the hydrogen of water combines with the oxygen of the carbonic acid. In the former of these cases, the two equivalents of oxygen in the carbonic acid must be liberated ; in the latter, two atoms of water must be decomposed, the hydrogen of which unites with the oxygen of the carbonic acid, whilst the oxygen of the water, thus set free, is disengaged in the state of a gas. It was considered most probable that the latter was the case.

From their generating caoutchouc, wax, fats, and volatile oils containing hydrogen in large quantity, and no oxygen, we may be certain that plants possess the property of decomposing water, because from no other body could they obtain the hydrogen of those matters. It has also been proved by the observations of Humboldt on the fungi, that water may be decomposed without the assimilation of hydrogen. Water is a remarkable combination of two elements, which have the power to separate themselves from one another, in innumerable processes, in a manner imperceptible to our senses ; while carbonic acid, on the contrary, is only decomposable by violent chemical action.

Most vegetable structures contain hydrogen in the form of water, which can be separated as such, and replaced by other bodies ; but the hydrogen which is essential to their constitution cannot possibly exist in the state of water.

All the hydrogen necessary for the formation of an organic compound is supplied to a plant by the decomposition of water. The process of assimilation, in its most simple form, consists in the extraction of hydrogen from water, and carbon from carbonic acid, in consequence of which, either all the oxygen of the water and carbonic acid is separated, as in the formation of caoutchouc, the volatile oils which contain no oxygen, and other similar substances, or only a part of it is exhaled.

The known composition of the organic compounds most generally present in vegetables, enables us to state in definite proportions the quantity of oxygen separated during their formation.

36 eq. carbonic acid and 22 eq. hydrogen derived ⎱
    from 22 eq. water   .   .   .   . ⎰ = *Woody Fibre,*
           with the separation of 72 eq. oxygen.

36 eq. carbonic acid and 36 eq. hydrogen derived ⎱
    from 36 eq. water   .   .   .   . ⎰ = *Sugar,*
           with the separation of 72 eq. oxygen.

36 eq. carbonic acid and 30 eq. hydrogen derived ⎱
    from 30 eq. water   .   .   .   . ⎰ = *Starch,*
           with the separation of 72 eq. oxygen.

36 eq. carbonic acid and 16 eq. hydrogen derived ⎱
    from 16 eq. water   .   .   .   . ⎰ = *Tannic Acid,*
           with the separation of 64 eq. oxygen.

36 eq. carbonic acid and 18 eq. hydrogen derived ⎱
    from 18 eq. water   .   .   .   . ⎰ = *Tartaric Acid,*
           with the separation of 45 eq. oxygen.

36 eq. carbonic acid and 18 eq. hydrogen derived ⎱
    from 18 eq. water   .   .   .   . ⎰ = *Malic Acid,*
           with the separation of 54 eq. oxygen.

36 eq. carbonic acid and 24 eq. hydrogen derived ⎱
    from 24 eq. water   .   .   .   . ⎰ = *Oil of Turpentine,*

It will readily be perceived that the formation of the
acids is accompanied with the smallest separation of
oxygen; that the amount of oxygen set free increases
with the production of the so-named neutral substances,
and reaches its maximum in the formation of the oils.
Fruits remain acid in cold summers; while the most
numerous trees under the tropics are those which produce
oils, caoutchouc, and other substances containing very
little oxygen.   The action of sunshine and influence of
heat upon the ripening of fruit is thus, in a certain
measure, represented by the numbers above cited.

The green resinous principle of the leaf diminishes in
quantity, while oxygen is absorbed, when fruits are
ripened in the dark; red and yellow colouring matters
are formed; tartaric, citric, and tannic acids disappear,
and are replaced by sugar, amylin, or gum.   6 eq. *Tar-
taric Acid*, by absorbing 6 eq. oxygen from the air, form
Grape Sugar, with the separation of 12 eq. carbonic acid.
1 eq. *Tannic Acid*, by absorbing 8 eq. oxygen from the
air, and 4 eq. water, form 1 eq. of *Amylin*, or starch, with
separation of 6 eq. carbonic acid.

We can explain, in a similar manner, the formation of
all the component substances of plants which contain no
nitrogen, whether they are produced from carbonic acid
and water, with separation of oxygen, or by the conver-
sion of one substance into the other, by the assimilation
of oxygen and separation of carbonic acid.   We do not
know in what form the production of these constituents
takes place; in this respect the representation of their
formation which we have given must not be received in
an absolute sense, it being intended only to render the
nature of the process more capable of apprehension; but
it must not be forgotten that if the conversion of tartaric

acid into sugar, in grapes, be considered as a fact, it must take place under all circumstances in the same proportions.

The vital process in plants is, with reference to the point we have been considering, the very reverse of the chemical processes engaged in the formation of salts. Carbonic acid, zinc, and water, when brought into contact, act upon one another, and *hydrogen is separated*, while a white pulverulent compound is formed, which contains carbonic acid, zinc, and the oxygen of the water. A living plant represents the zinc in this process: but the process of assimilation gives rise to compounds, which contain the elements of carbonic acid and the hydrogen of water, whilst *oxygen is separated*.

Decay has been described above as the great operation of nature, by which that oxygen, which was assimilated by plants during life, is again returned to the atmosphere. During the progress of growth, plants appropriate carbon in the form of carbonic acid, and hydrogen from the decomposition of water, the oxygen of which is set free, together with a part of all of that contained in the carbonic acid. In the process of putrefaction, a quantity of water exactly corresponding to that of the hydrogen, is again formed by extraction of oxygen from the air; while all the oxygen of the organic matter is returned to the atmosphere in the form of carbonic acid. Vegetable matters can emit carbonic acid, during their decay, only in proportion to the quantity of oxygen which they contain; acids, therefore, yield more carbonic acid than neutral compounds; while fatty acids, resin, and wax, do not putrify; they remain in the soil without any apparent change.

The numerous springs which emit carbonic acid in the

neighbourhood of extinct volcanoes, must be regarded as another means of compensating for the carbonic acid absorbed and retained by plants during life, and consequently as a source by which oxygen is supplied to the atmosphere. Bischof calculated that the springs of carbonic acid in the *Eifel* (a volcanic district near Coblentz) send into the air every day more than 110,000 lbs. of carbonic acid, corresponding to 79,000 lbs. of pure oxygen.

CHAPTER V.

We cannot suppose that a plant could attain maturity, even in the richest vegetable mould, without the presence of matter containing nitrogen; since we know that nitrogen exists in every part of the vegetable structure. The first and most important question to be solved, therefore, is : How and in what form does nature furnish nitrogen to vegetable albumen, and gluten, to fruits and seeds ?

This question is susceptible of a very simple solution:

Plants, as we know, grow perfectly well in pure charcoal, if supplied at the same time with rain-water. Rain-water can contain nitrogen only in two forms, either as dissolved atmospheric air, or as ammonia, which consists of this element and hydrogen. Now, the nitrogen of the air cannot be made to enter into combination with any element except oxygen, even by the employment of the most powerful chemical means. We have not the slightest reason for believing that the nitrogen of the atmosphere takes part in the processes of assimilation of plants and animals; on the contrary, we know that many plants emit the nitrogen which is absorbed by their roots, either in the gaseous form, or in solution in water. But there are on the other hand numerous facts, showing, that the formation in plants of substances containing nitrogen, such as gluten, takes place in proportion to the quantity of this

element which is conveyed to their roots in the state of ammonia, derived from the putrefaction of animal matter.

Ammonia, too, is capable of undergoing such a multitude of transformations, when in contact with other bodies, that in this respect it is not inferior to water, which possesses the same property in an eminent degree. It possesses properties which we do not find in any other compound of nitrogen : when pure, it is extremely soluble in water ; it forms soluble compounds with all the acids ; and when in contact with certain other substances, it completely resigns its character as an alkali, and is capable of assuming the most various and opposite forms. Formate of ammonia changes, under the influence of a high temperature, into hydrocyanic acid and water, without the separation of any of its elements. Ammonia forms urea, with cyanic acid, and a series of crystalline compounds, with the volatile oils of mustard and bitter almonds. It changes into splendid blue or red colouring matters, when in contact with the bitter constituent of the bark of the apple-tree (*phloridzin*), with the sweet principle of the *Variolaria dealbata* (*orcin*), or with the tasteless matter of the *Rocella tinctoria* (*erythrin*). All blue colouring matters which are rendered by acids, and all red colouring substances which are rendered blue by alkalies, contain nitrogen, but not in the form of a base.

These facts are not sufficient to establish the opinion that it is ammonia which affords all vegetables, without exception, the nitrogen which enters into the composition of their constituent substances. Considerations of another kind, however, give to this opinion a degree of certainty which completely excludes all other views of the matter.

Let us picture to ourselves the condition of a well-cultured farm, so large as to be independent of assistance

from other quarters.   On this extent of land there is a
certain quantity of nitrogen contained both in the corn
and fruit which it produces, and in the men and animals
which feed upon them, and also in their excrements.   We
shall suppose this quantity to be known.   The land is
cultivated without the importation of any foreign substance
containing nitrogen.   Now, the products of this farm
must be exchanged every year for money, and other
necessaries of life—for bodies, therefore, which contain no
nitrogen.   A certain proportion of nitrogen is exported
with corn and cattle; and this exportation takes place
every year, without the smallest compensation; yet after
a given number of years, the quantity of nitrogen will be
found to have increased.   Whence, we may ask, come
this increase of nitrogen?   The nitrogen in the excrements
cannot reproduce itself, and the earth cannot yield it.
Plants, and consequently animals, must, therefore, derive
their nitrogen from the atmosphere.

It will in a subsequent part of this work be shown that
the last products of the decay and putrefaction of animal
bodies present themselves in two different forms.   They
are in the form of a combination of hydrogen and nitrogen
—*ammonia*—in the temperate and cold climates, and in
that of a compound containing oxygen—*nitric acid*—in
the tropics and hot climates.   The formation of the latter
is preceded by the production of the first.   Ammonia is
the last product of the putrefaction of animal bodies;
nitric acid is the product of the transformation of ammo-
nia.   A generation of a thousand million men is renewed
every thirty years : thousands of millions of animals cease
to live, and are reproduced, in a much shorter period.
Where is the nitrogen which they contained during life?
There is no question which can be answered with more

positive certainty. All animal bodies during their decay yield the nitrogen which they contain to the atmosphere, in the form of ammonia. Even in the bodies buried sixty feet under ground in the churchyard of the Eglise des Innocens, at Paris, all the nitrogen contained in the adipocire was in the state of ammonia. Ammonia is the simplest of all the compounds of nitrogen; and hydrogen is the element for which nitrogen possesses the most powerful affinity.

The nitrogen of putrified animals is contained in the atmosphere as ammonia, in the form of a gas which is capable of entering into combination with carbonic acid and of forming a volatile salt. Ammonia in its gaseous form, as well as all its volatile compounds, is of extreme solubility in water. Ammonia, therefore, cannot remain long in the atmosphere, as every shower of rain must condense it, and convey it to the surface of the earth. Hence also, rain-water must at all times contain ammonia, though not always in equal quantity. It must be greater in summer than in spring or in winter, because the intervals of time between the showers are in summer greater; and when several wet days occur, the rain of the first must contain more of it than that of the second. The rain of a thunder-storm, after a long-protracted drought, ought for this reason to contain the greatest quantity which is conveyed to the earth at one time.

But we have formerly stated, that all the analyses of atmospheric air hitherto made have failed to demonstrate the presence of ammonia, although, according to our view, it can never be absent. Is it possible that it could have escaped our most delicate and most exact apparatus? The quantity of nitrogen contained in a cubic foot of air is certainly extremely small, but, notwithstanding this,

the sum of the quantities of nitrogen from thousands and millions of dead animals is more than sufficient to supply all those living at one time with this element.

From the tension of aqueous vapour at 15° C. (59° F.) = 6,98 lines (Paris measure), and from its known specific gravity at 0° C. (32° F.), it follows that when the temperature of the air is 59° F. and the height of the barometer 28", 1 cubic metre or 35·3 cubic feet of aqueous vapour are contained in 487 cubic metres, or 17,191 cubic feet of air; 35·3 cubic feet of aqueous vapour weigh about 1½ lb. Consequently, if we suppose that the air saturated with moisture at 59° F. allows all the water which it contains in the gaseous form to fall as rain, then 1·1 pound of rain-water must be obtained from every 11,471 cubic feet of air. The whole quantity of ammonia contained in the same number of cubic feet will also be returned to the earth in this one pound of rain-water. But if the 11,471 cubic feet of air contain a single grain of ammonia, then ten cubic inches—the quantity usually employed in an analysis—must contain only 0·000000048 of a grain. This extremely small proportion is absolutely inappreciable by the most delicate and best eudiometer; it might be classed among the errors of observation, even were its quantity ten thousand times greater. But the detection of ammonia must be much more easy when a pound of rain-water is examined, for this contains all the gas that was diffused through 11,471 cubic feet of air.

If a pound of rain-water contain only ¼th of a grain of ammonia, then a field of 26,910 square feet must receive annually upwards of 88 lbs. of ammonia, or 71 lbs. of nitrogen; for by the observations of Schubler, which were formerly alluded to, about 770,000 lbs. of rain fall over this surface in four months, and consequently the annual fall

must be 2,310,000 lbs. This is much more nitrogen
than is contained in the form of vegetable albumen and
gluten, in 2920 lbs. of wood, 3085 lbs. of hay, or 200
cwt. of beet-root, which are the yearly produce of such a
field; but it is less than the straw, roots, and grain of
corn, which might grow on the same surface, would
contain *.

Experiments made in this laboratory (Giessen) with
the greatest care and exactness have placed the presence
of ammonia in rain-water beyond all doubt.   It has
hitherto escaped observation, because no person thought
of searching for it.   All the rain-water employed in this
inquiry was collected 600 paces south-west of Giessen,
whilst the wind was blowing in the direction of the town.
When several hundred pounds of it were distilled in
a copper still, and the first two or three pounds evapo-
rated with the addition of a little muriatic acid, a very
distinct crystallisation of sal-ammoniac was obtained :
the crystals had always a brown or yellow colour.

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* The advocates of the importance of humus as a nourishment for
plants, being driven from their position by the facts brought forward in
the preceding chapters, have found in the ammonia of the atmosphere an
explanation of the manner in which humus acquires its solubility, and there-
fore its capability of being assimilated by plants.   Now, it is very true
that humic acid is soluble in ammonia ; but the humic acid of chemists *is
not contained in soils*.   Were it so, on treating mould with water we should
obtain a dark-coloured solution of humate of ammonia.   But we obtain a
solution which is entirely devoid of this acid.   It cannot be too distinctly
kept in mind that *humic acid* is the product of the decomposition of
humus, by means of caustic alkalies.   Again, if the coloured solutions of
humates of ammonia, lime, or magnesia, be poured upon good mould or
decayed oak-wood (which is nearly pure *humus*), and allowed to filter,
the solutions are observed to pass through quite colourless ; they are
decolourised just as if they had been filtered through charcoal.   Here,
then, *humus* possesses the property of extracting *humic acid* from water ;
or, in other words, soils have the power of rendering humic acid inso-
luble, or unfit for assimilation.—ED.

Ammonia may likewise be always detected in snow-water. Crystals of sal-ammoniac were obtained by evaporating in a vessel with muriatic acid several pounds of snow, which were gathered from the surface of the ground in March, when the snow had a depth of 10 inches. Ammonia was set free from these crystals by the addition of hydrate of lime. The inferior layers of snow which rested upon the ground contained a quantity decidedly greater than those which formed the surface.

It is worthy of observation that the ammonia contained in rain and snow water possesses an offensive smell of perspiration and animal excrements,—a fact which leaves no doubt respecting its origin.

Hünefield has proved that all the springs in Greifswalde, Wick, Eldena, and Kostenhagen, contain carbonate and nitrate of ammonia. Ammoniacal salts have been discovered in many mineral springs in Kissingen and other places. The ammonia of these salts can only arise from the atmosphere.

Any one may satisfy himself of the presence of ammonia in rain by simply adding a little sulphuric or muriatic acid to a quantity of rain-water, and evaporating this nearly to dryness in a clean porcelain basin. The ammonia remains in the residue, in combination with the acid employed; and may be detected either by the addition of a little chloride of platinum, or more simply by a little powdered lime, which separates the ammonia, and thus renders its peculiar pungent smell sensible *. The

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* Since the appearance of the last edition, this experiment has been repeated by many in France, Germany, America, and England, and the existence of ammonia in the atmosphere has been completely confirmed. The assertion that this ammonia possesses the " offensive smell of perspiration and animal excrements," has been ridiculed by many as fanciful

sensation which is perceived upon moistening the hand with rain-water, so different from that produced by pure distilled water, and to which the term *softness* is vulgarly applied, is also due to the carbonate of ammonia contained in the former.

The ammonia which is removed from the atmosphere by rain and other causes, is as constantly replaced by the putrefaction of animal and vegetable matters. A certain portion of that which falls with the rain evaporates again with the water, but another portion is, we suppose, taken up by the roots of plants, and entering into new combinations in the different organs of assimilation, produces albumen, gluten, quinine, morphia, cyanogen, and a number of other compounds containing nitrogen. The chemical characters of ammonia render it capable of entering into such combinations, and of undergoing numerous transformations. We have now only to consider whether it really is taken up in the form of ammonia by the roots of plants, and in that form applied by their organs to the production of the azotised matters contained in them. This question is susceptible of easy solution by well-known facts.

In the year 1834, I was engaged with Dr. Wilbrand, professor of botany in the university of Giessen, in an investigation respecting the quantity of sugar contained in different varieties of maple-trees, which grew upon* soils which were not manured. We obtained crystallised sugars from all, by simply evaporating their juices, without the addition of any foreign substance; and we unexpectedly made the observation, that a great quantity of

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—by none, however, who have made the experiment. The experiment is so exceedingly easy to perform, that any one may convince himself of the accuracy of the statement.—ED.

ammonia was emitted from this juice when mixed with lime, and also from the sugar itself during its refinement. The vessels which hung upon the trees in order to collect the juice were watched with greater attention, on account of the suspicion that some evil-disposed persons had introduced urine into them, but still a large quantity of ammonia was again found in the form of neutral salts. The juice had no colour, and had no reaction on that of vegetables. Similar observations were made upon the juice of the birch-tree ; the specimens subjected to experiment were taken from a wood several miles distant from any house, and yet the clarified juice, evaporated with lime, emitted a strong odour of ammonia.

In the manufactories of beet-root sugar, many thousand cubic feet of juice are daily purified with lime, in order to free it from vegetable albumen and gluten, and it is afterwards evaporated for crystallisation. Every person who has entered such a manufactory must have been astonished at the great quantity of ammonia which is volatilised along with the steam. This ammonia must be contained in the form of an ammoniacal salt, because the neutral juice possesses the same characters as the solution of such a salt in water ; it acquires, namely, an acid reaction during evaporation, in consequence of the neutral salt being converted by loss of ammonia into an acid salt. The free acid which is thus formed is a source of loss to the manufacturers of sugar from beet-root, by changing a part of the sugar into uncrystallisable grape sugar and syrup.

The products of the distillation of flowers, herbs, and roots, with water, and all extracts of plants made for medicinal purposes, contain ammonia. The unripe, transparent, and gelatinous pulp of the almond and peach emit

much ammonia when treated with alkalies. (Robiquet.) The juice of the fresh tobacco leaf contains ammoniacal salts. The water which exudes from a cut vine, when evaporated with a few drops of muriatic acid, also yields a gummy deliquescent mass, which evolves much ammonia on the addition of lime. Ammonia exists in every part of plants, in the roots (as in beet-root), in the stem (of the maple-tree), and in all blossoms and fruit in an unripe condition.

The juices of the maple and birch contain both sugar and ammonia, and therefore afford all the conditions necessary for the formation of the azotised components of the branches, blossoms, and leaves, as well as of those which contain no azote or nitrogen. In proportion as the development of those parts advances, the ammonia diminishes in quantity, and when they are fully formed, the tree yields no more juice.

The employment of animal manure in the cultivation of grain, and the vegetables which serve for fodder to cattle, is the most convincing proof that the nitrogen of vegetables is derived from ammonia. The quantity of gluten in wheat, rye, and barley, is very different; these kinds of grain also, even when ripe, contain this compound of nitrogen in very different proportions. Proust found French wheat to contain 12·5 per cent. of gluten; Vogel found that the Bavarian contained 24 per cent.; Davy obtained 19 per cent. from winter, and 24 from summer wheat; from Sicilian 21, and from Barbary wheat 19 per cent. The meal of Alsace wheat contains, according to Boussingault, 17·3 per cent. of gluten; that of wheat grown in the "Jardin des Plantes" 26·7, and that of winter wheat 3·33 per cent. Such great differences must be owing to some cause, and this we

find in the different methods of cultivation. An increase of animal manure gives rise not only to an increase in the number of seeds, but also to a most remarkable difference in the proportion of the substances containing nitrogen, such as the gluten which they contain.

Animal manure, in as far as regards the assimilation of nitrogen, acts only by the formation of ammonia. One hundred parts of wheat grown on a soil manured with cow-dung (a manure containing the smallest quantity of nitrogen), afforded only 11·95 parts of gluten, and 64·34 parts of amylin, or starch; whilst the same quantity, grown on a soil manured with human urine, yielded the maximum of gluten, namely 35·1 per cent. Putrified urine contains nitrogen in the forms of carbonate, phosphate, and lactate of ammonia, and in no other form than that of ammoniacal salts.

" Putrid urine is employed in Flanders as a manure with the best results. During the putrefaction of urine, ammoniacal salts are formed in large quantity, it may be said exclusively; for under the influence of heat and moisture, urea, the most prominent ingredient of the urine, is converted into carbonate of ammonia. The barren soil on the coast of Peru is rendered fertile by means of a manure called *Guano*, which is collected from several islands in the South Sea*. It is sufficient to add a small quantity of guano to a soil, which consists only of sand and clay, in order to procure the richest crop of maize. The soil itself does not contain the smallest particle of organic matter, and the manure employed is formed only

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* The guano, which forms a stratum several feet in thickness upon the surface of these islands, consists of the putrid excrements of innumerable sea-fowl that remain on them during the breeding season. (See the Chapter on Manures.)

of *urate, phosphate, oxalate,* and *carbonate of ammonia,*
together with a few earthy salts*."

Ammonia, therefore, must have yielded the nitrogen to
these plants.   Gluten is obtained not only from corn, but
also from grapes and other plants ; but that extracted
from the grapes is called vegetable albumen, although
it is identical in composition and properties with the
ordinary gluten.

It is ammonia which yields nitrogen to the vegetable
albumen, the principal constituent of plants ; and it must
be ammonia which forms the red and blue colouring
matters of flowers.   Nitrogen is not presented to wild
plants in any other form capable of assimilation.   Ammo-
nia, by its transformation, furnishes nitric acid to the
tobacco plant, sun-flower, *Chenopodium,* and *Borago
officinalis,* when they grow in a soil completely free from
nitre.   Nitrates are necessary constituents of these plants,
which thrive only when ammonia is present in large
quantity, and when they are also subject to the influence
of the direct rays of the sun, an influence necessary to
effect the disengagement within their stem and leaves of
the oxygen, which shall unite with the ammonia to form
nitric acid.

The urine of men and of carnivorous animals contains
a large quantity of nitrogen, partly in the form of phos-
phates, partly as urea.   Urea is converted during putre-
faction into carbonate of ammonia, that is to say, it takes
the form of the very salt which occurs in rain-water.
Human urine is the most powerful manure for all vege-
tables containing nitrogen ; that of horses and horned
cattle contains less of this element, but infinitely more
than the solid excrements of these animals.   In addition

* Boussingault, Ann. de Ch. et de Phys. lxv. p. 219.

to urea, the urine of herbivorous animals contains hip-
puric acid, which is decomposed during putréfaction into
benzoic acid and ammonia. The latter enters into the
composition of the gluten, but the benzoic acid often
remains unchanged; for example, in the *Anthoxanthum
odoratum.*

The solid excrements of animals contain comparatively
very little nitrogen, but this could not be otherwise. The
food taken by animals supports them only in so far as it
offers elements for assimilation to the various organs
which they may require for their increase or renewal.
Corn, grass, and all plants, without exception, contain
azotised substances. The quantity of food which animals
take for their nourishment, diminishes or increases in the
same proportion as it contains more or less of the sub-
stances containing nitrogen. A horse may be kept alive
by feeding it with potatoes, which contain a very small
quantity of nitrogen; but life thus supported is a
gradual starvation; the animal increases neither in size
nor strength, and sinks under every exertion. The
quantity of rice which an Indian eats astonishes the
European; but the fact that rice contains less nitrogen
than any other kind of grain at once explains the circum-
stance.

Now, as it is evident that the nitrogen of the plants
and seeds used by animals as food must be employed in
the process of assimilation, it is natural to expect that the
excrements of these animals will be deprived of it in pro-
portion to the perfect digestion of the food, and can only
contain it when mixed with secretions from the liver and
intestines. Under all circumstances, they must contain
less nitrogen than the food. When, therefore, a field is
manured with animal excrements, a smaller quantity of

matter containing nitrogen is added to it than has been
taken from it in the form of grass, herbs, or seeds. By
means of manure, an addition only is made to the nourish-
ment which the air supplies.

In a scientific point of view, it should be the care of
the agriculturist so to employ all the substances contain-
ing a large proportion of nitrogen which his farm affords
in the form of animal excrements, that they shall serve as
nutriment to his own plants. This will not be the case
unless those substances are properly distributed upon his
land. A heap of manure lying unemployed upon his
land would serve him no more than his neighbours. The
nitrogen in it would escape as carbonate of ammonia into
the atmosphere, and a mere carbonaceous residue of
decayed plants would, after some years, be found in its
place.

All animal excrements emit carbonic acid and ammonia,
as long as nitrogen exists in them. In every stage of
their putrefaction an escape of ammonia from them may
be induced by moistening them with a potash ley ; the
ammonia being apparent to the senses by a peculiar smell,
and by the dense white vapour which arises when a solid
body moistened with an acid is brought near it. This
ammonia evolved from manure is imbibed by the soil
either in solution in water, or in the gaseous form, and
plants thus receive a larger supply of nitrogen than is
afforded to them by the atmosphere.

But it is much less the quantity of ammonia, yielded
to a soil by animal excrements, than the form in which it
is presented by them, that causes their great influence on
its fertility. Wild plants obtain more nitrogen from the
atmosphere in the form of ammonia than they require
for their growth, for the water which evaporates through

their leaves and blossoms, emits, after some time, a putrid
smell, a peculiarity possessed only by such bodies as con-
tain nitrogen. Cultivated plants receive the same quan-
tity of nitrogen from the atmosphere as trees, shrubs, and
other wild plants; but this is not sufficient for the pur-
poses of agriculture. Agriculture differs essentially from
the cultivation of forests, inasmuch as its principal object
consists in the production of nitrogen under any form
capable of assimilation; whilst the object of forest culture
is confined principally to the production of carbon. All
the various means of culture are subservient to these two
main purposes. A part only of the carbonate of ammonia
which is conveyed by rain to the soil is received by
plants, because a certain quantity of it is volatilised with
the vapour of water; only that portion of it can be assi-
milated which sinks deeply into the soil, or which is con-
veyed directly to the leaves by dew, or is absorbed from
the air along with the carbonic acid.

Liquid animal excrements, such as the urine with
which the solid excrements are impregnated, contain the
greatest part of their ammonia in the state of salts, in a
form, therefore, in which it has completely lost its vola-
tility; when presented in this condition, not the smallest
portion of the ammonia is lost to the plants; it is all dis-
solved by water, and imbibed by their roots. The
evident influence of gypsum upon the growth of grasses
—the striking fertility and luxuriance of a meadow upon
which it is strewed—depends only upon its fixing in the
soil the ammonia of the atmosphere, which would other-
wise be volatilised, with the water which evaporates*.

* It has long been the practice in some parts of the country to strew
the floors of stables with gypsum. This prevents the disagreeable odour
arising from the putrefaction of stable manure, by decomposing the
ammoniacal salts which are formed.—ED.

The carbonate of ammonia contained in rain-water is decomposed by gypsum, in precisely the same manner as in the manufacture of sal-ammoniac. Soluble sulphate of ammonia and carbonate of lime are formed ; and this salt of ammonia possessing no volatility is consequently retained in the soil. All the gypsum gradually disappears, but its action upon the carbonate of ammonia continues as long as a trace of it exists.

The beneficial influence of gypsum and of many other salts has been compared to that of aromatics, which increase the activity of the human stomach and intestines, and give a tone to the whole system. But plants contain no nerves; we know of no substance capable of exciting them to intoxication and madness, or of lulling them to sleep and repose. No substance can possibly cause their leaves to appropriate a greater quantity of carbon from the atmosphere, when the other constituents which the seeds, roots, and leaves require for their growth are wanting. The favourable action of small quantities of aromatics upon man, when mixed with his food, is undeniable ; but aromatics are given to plants *without food* to be digested, and still they flourish with greater luxuriance.

It is quite evident, therefore, that the common view concerning the influence of certain salts upon the growth of plants evinces only ignorance of its cause.

The action of gypsum or chloride of calcium really consists in their giving a fixed condition to the nitrogen —or ammonia which is brought into the soil, and which is indispensable for the nutrition of plants.

In order to form a conception of the effect of gypsum, it may be sufficient to remark that 110 lbs. of burned gypsum fixes as much ammonia in the soil as 6880 lbs. o

horse's urine* would yield to it, even on the supposition that all the nitrogen of the urea and hippuric acid were absorbed by the plants without the smallest loss, in the form of carbonate of ammonia. If we admit with Boussingault† that the nitrogen in grass amounts to $\frac{1}{100}$ of its weight, then every pound of nitrogen which we add increases the produce of the meadow 100 lbs.; and this increased produce of 100 lbs. is effected by the aid of a little more than 4 lbs. of gypsum.

Water is absolutely necessary to effect the decomposition of the gypsum, on account of its difficult solubility, (1 part of gypsum requires 400 parts of water for solution,) and also to assist in the absorption of the sulphate of ammonia by the plants: hence it happens, that the influence of gypsum is not observable on dry fields and meadows. In such it would be advisable to employ a salt of more easy solubility, such as chloride of calcium.

The decomposition of gypsum by carbonate of ammonia does not take place instantaneously; on the contrary, it proceeds very gradually, and this explains why the action of the gypsum lasts for several years.

The advantage of manuring fields with burned clay, and the fertility of ferruginous soils, which have been considered as facts so incomprehensible, may be explained in an equally simple manner. They have been ascribed to the great attraction for water, exerted by dry clay and

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* The urine of the horse contains, according to Fourcroy and Vauquelin, in 1000 parts,

Urea	7 parts.
Hippurate of soda . .	24 ,,
Salts and water . . .	979 ,,

1000 parts.

† Boussingault, Ann. de Ch. et de Phys. t. lxiii. page 243.

ferruginous earth ; but common dry arable land possesses this property in as great a degree: and besides, what influence can be ascribed to a hundred pounds of water spread over an acre of land, in a condition in which it cannot be serviceable either by the roots or leaves ? . The true cause is this :—

The oxides of iron and alumina are distinguished from all other metallic oxides by their power of forming solid compounds with ammonia. The precipitates obtained by the addition of ammonia to salts of alumina or iron are true salts, in which the ammonia is contained as a base. Minerals containing alumina or oxide of iron also possess, in an eminent degree, the remarkable property of attracting ammonia from the atmosphere and of retaining it. Vauquelin, whilst engaged in the trial of a criminal case, discovered that all rust of iron contains a certain quantity of ammonia. Chevalier afterwards found that ammonia is a constituent of all minerals containing iron ; that even hematite, a mineral which is not at all porous, contains one per cent. of it. Bouis showed also, that the peculiar odour observed on moistening minerals containing alumina, is partly owing to their exhaling ammonia. Indeed, gypsum and some varieties of alumina, pipe-clay for example, emit so much ammonia, when moistened with caustic potash, that even after they have been exposed for two days, reddened litmus paper held over them becomes blue. Soils, therefore, which contain oxides of iron, and burned clay, must absorb ammonia, an action which is favoured by their porous condition; they further prevent the escape of the ammonia once absorbed by their chemical properties. Such soils, in fact, act precisely as a mineral acid would do, if extensively spread over their surface; with this difference, that the acid

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would penetrate the ground, enter into combination with lime, alumina, and other bases, and thus lose, in a few hours, its property of absorbing ammonia from the atmosphere. The addition of burned clay to soils has also a secondary influence; it renders the soil porous, and, therefore, more permeable to air and moisture.

The ammonia absorbed by the clay or ferruginous oxides is separated by every shower of rain, and conveyed in solution to the soil.

Powdered charcoal possesses a similar action, but surpasses all other substances in the power which it possesses of condensing ammonia within its pores, particularly when it has been previously heated to redness. Charcoal absorbs 90 times its volume of ammoniacal gas, which may be again separated by simply moistening it with water. (De Saussure.) Decayed wood approaches very nearly to charcoal in this power; decayed oak-wood absorbs 72 times its volume, after having been completely dried under the air-pump. We have here an easy and satisfactory means of explaining still further the properties of humus, or wood in a decaying state. It is not only a slow and constant source of carbonic acid, but it is also a means by which the necessary nitrogen is conveyed to plants.

Nitrogen is found in lichens, which grow on basaltic rocks. Our fields produce more of it than we have given them as manure, and it exists in all kinds of soils and minerals which were never in contact with organic substances. The nitrogen in these cases could only have been extracted from the atmosphere.

We find this nitrogen in the atmosphere in rain-water and in all kinds of soils, in the form of ammonia, as a product of the decay and putrefaction of preceding gene-

rations of animals and vegetables. We find likewise that the proportion of azotised matters in plants is augmented by giving them a larger supply of ammonia conveyed in the form of animal manure.

No conclusion can then have a better foundation than this, that it is the ammonia of the atmosphere which furnishes nitrogen to plants.

Carbonic acid, water and ammonia, contain the elements necessary for the support of animals and vegetables. The same substances are the ultimate products of the chemical processes of decay and putrefaction. All the innumerable products of vitality resume, after death, the original form from which they sprung. And thus death—the complete dissolution of an existing generation—becomes the source of life for a new one.

CHAPTER VI.

OF THE INORGANIC CONSTITUENTS OF PLANTS.

CARBONIC acid, water and ammonia, are necessary for the existence of plants, because they contain the elements from which their organs are formed ; but other substances are likewise requisite for the formation of certain organs destined for special functions peculiar to each family of plants. Plants obtain these substances from inorganic nature. In the ashes left after the incineration of plants, the same substances are found, although in a changed condition.

Although the vital principle exercises a great power over chemical forces, yet it does so only by directing the way in which they are to act, and not by changing the laws to which they are subject. Hence when the chemical forces are employed in the processes of vegetable nutrition, they must produce the same results which are observed in ordinary chemical phenomena. The inorganic matter contained in plants must, therefore, be subordinate to the laws which regulate its combinations in common chemical processes.

The most important division of inorganic substances is that of *acids* and *alkalies*. Both of these have a tendency to unite together, and form neutral compounds, which are termed salts. According to the doctrine of equivalents, these combinations are always effected in definite propor-

tions, that is to say, one equivalent of an acid always unites with one or two equivalents of a base, whatever that base may be. Thus 501·17 parts by weight of sulphuric acid unite with 1 eq. of potash, and form 1 eq. of sulphate of potash; the same quantity unites with 1 eq. of soda, and produces sulphate of soda. From this fact follows the rule—that the quantity, which an acid requires of an alkali for its saturation, may be represented by a very simple number.

It is perfectly necessary to form a proper conception of what chemists denominate the " capacity for saturation of an acid," before we are able to form a correct idea of the functions performed in plants, by their inorganic constituents. The power of a base to neutralize an acid does not depend upon the quantity of radical which it contains, but altogether upon the quantity of its oxygen. Thus protoxide of iron contains 1 eq. of oxygen, and unites with 1 eq. of sulphuric acid in forming a neutral salt; but peroxide of iron contains 3 eq. of oxygen, and requires 3 eq. of the same acid for its neutralization. Hence when a given weight of an acid is neutralized by different bases, the quantity of oxygen contained in these bases must be the same as is exhibited by the following scale :—

501·17 parts of Sulphuric Acid neutralize	258·35 Magnesia	Oxygen=100
,, ,, ,,	647·29 Strontia	,, =100
,, ,, ,,	1451·61 Oxide of Silver	,, =100
,, ,, ,,	956·8 Barytes	,, =100

It follows from the law of equivalents, that the quantity of oxygen in a base must stand in a simple relation to the quantity of oxygen in an acid which unites with it. By this is meant, that the quantities in both cases must either be equal or multiples of each other; for the doctrine of equivalents denies the possibility of their

uniting in fractional parts. This will be rendered obvious
by a consideration of the two following examples :

100 parts of Cyanic Acid contain 23·26 oxygen = 1.

100 parts of Cyanic Acid saturate 137·21 parts of potash, which contain
    23·26 oxygen = 1.

100 parts of Nitric Acid contain 73·85 oxygen = 5.

100 parts of Nitric Acid saturate 214·40 parts of oxide of silver, which
    contain 14·77 oxygen = 1.

In the first of these cases, the relation of the oxygen of
the base to that of the acid is as 1:1 ; in the second, as 1:5.
The capacity for saturation of each acid is, therefore, the
constant quantity of oxygen necessary to neutralize 100
parts of it.

Many of the inorganic constituents vary according to
the soil in which the plants grow, but a certain number
of them are indispensable to their development. All sub-
stances in solution in a soil are absorbed by the roots of
plants, exactly as a sponge imbibes a liquid, and all that
it contains, without selection. The substances thus con-
veyed to plants are retained in greater or less quantity,
or are entirely separated when not suited for assimilation.

Phosphate of magnesia in combination with ammonia
is an invariable constituent of the seeds of all kinds of
grasses. It is contained in the outer horny husk, and is
introduced into bread along with the flour, and also into
beer. The bran of flour contains the greatest quantity of
it. It is this salt which forms large crystalline concre-
tions, often amounting to several pounds in weight, in the
cæcum of horses belonging to millers ; and when ammo-
nia is mixed with beer, the same salt separates as a
white precipitate.

Most plants, perhaps all of them, contain organic acids
of very different composition and properties, all of which
are in combination with bases, such as potash, soda, lime,

or magnesia. These bases evidently regulate the forma-
tion of the acids, for the diminution of the one is followed
by a decrease of the other : thus in the grape, for example,
the quantity of potash contained in its juice is less when
it is ripe than when unripe; and the acids, under the
same circumstances, are found to vary in a similar man-
ner. Such constituents exist in small quantity in those
parts of a plant in which the process of assimilation is
most active, as in the mass of woody fibre; and their
quantity is greater in those organs whose office it is to
prepare substances conveyed to them for assimilation by
other parts. The leaves contain more inorganic matters
than the branches, and the branches more than the stem.
The potato plant contains more potash before blossom-
ing than after it.

The acids found in the different families of plants are
of various kinds; it cannot be supposed that their pre-
sence and peculiarities are the result of accident. The
fumaric and oxalic acids in the liverwort, the kinovic
acid in the *China nova*, the rocellic acid in the *Rocella
tinctoria*, the tartaric acid in grapes, and the numerous
other organic acids, must serve some end in vegetable
life. But if these acids constantly exist in vegetables,
and are necessary to their life, which is incontestable, it
is equally certain that some alkaline base is also indis-
pensable, in order to enter into combination with the
acids which are always found in the state of salts. All
plants yield by incineration ashes containing carbonic
acid; all therefore must contain salts of an organic acid*.

Now, as we know the capacity of saturation of organic
acids to be unchanging, it follows that the quantity of
the bases united with them cannot vary, and for this

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* Salts of organic acids yield carbonates on incineration, if they con-
tain either alkaline or earthy bases.

reason the latter substances ought to be considered with
the strictest attention both by the agriculturist and phy-
siologist.

We have no reason to believe that a plant in a condi-
tion of free and unimpeded growth produces more of its
peculiar acids than it requires for its own existence;
hence, a plant, on whatever soil it grows, must contain
an invariable quantity of alkaline bases. Culture alone
will be able to cause a deviation.

In order to understand this subject clearly, it will be
necessary to bear in mind that any one of the alkaline
bases may be substituted for another, the action of all
being the same. Our conclusion is therefore by no means
endangered by the existence of a particular alkali in one
plant, which may be absent in others of the same species.
If this inference be correct, the absent alkali or earth
must be supplied by one similar in its mode of action, or
in other words, by an equivalent of another base. The
number of equivalents of these various bases which may
be combined with a certain portion of acid must neces-
sarily be the same, and therefore the amount of oxygen
contained in them must remain unchanged under all cir-
cumstances and on whatever soil they grow.

Of course, this argument refers only to those alkaline
bases which in the form of organic salts form constituents
of the plants. Now, these salts are preserved in the
ashes of plants as carbonates, the quantity of which can
be easily ascertained.

It has been distinctly shown, by the analysis of De
Saussure and Berthier, that the nature of a soil exercises
a decided influence on the quantity of the different me-
tallic oxides contained in the plants which grow on it;
that magnesia, for example, was contained in the ashes
of a pine-tree grown at Mont Breven, whilst it was absent

from the ashes of a tree of the same species from Mont La Salle, and that even the proportion of lime and potash was very different.

Hence it has been concluded, (erroneously, I believe,) that the presence of bases exercises no particular influence upon the growth of plants : but even were this view correct, it must be considered as a most remarkable accident that these same analyses furnish proof for the very opposite opinion. For although the composition of the ashes of these pine-trees was so very different, they contained, according to the analyses of De Saussure, an equal number of equivalents of metallic oxides; or, what is the same thing, the quantity of oxygen contained in all the bases was in both cases the same.

100 parts of the ashes of the pine-tree from Mont Breven contained—

Carbonate of Potash .	3·60	Quantity of oxygen in the Potash	. 0·41
,, Lime .	46·34	,, ,, ,, Lime	. 7·33
,, Magnesia	6·77	,, ,, ,, Magnesia	1·27
Sum of the carbonates	56·71	Sum of the oxygen in the bases .	. 9·01

100 parts of the ashes of the pine from Mont La Salle contained*—

Carbonate of Potash .	7·36	Quantity of oxygen in the Potash	. 0·85
,, Lime .	51·19	,, ,, ,, Lime	. 8·10
,, Magnesia	00·00		
Sum of the carbonates	58·55	Sum of the oxygen in the bases .	. 8·95

The numbers 9·01 and 8·95 resemble each other as nearly as could be expected even in analyses made for

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* According to the experiments of Saussure, 1000 parts of the wood of the pine from Mont Brevon gave 11·87 parts of ashes ; the same quantity of wood from Mont La Salle yielded 11·28 parts. From this we might conclude that the two pines, although brought up in different soils, yet contained the same quantity of inorganic elements.

the very purpose of ascertaining the fact above demon-strated, which the analyst in this case had not in view.

Let us now compare Berthier's analyses of the ashes of two fir-trees, one of which grew in Norway, the other in Allevard (département de l'Isère). One contained 50, the other 25 per cent. of soluble salts. A greater difference in the proportion of the alkaline bases could scarcely exist between two totally different plants, and yet even here the quantity of oxygen in the bases of both was the same.

100 parts of the ashes of firwood from Allevard con-tained, according to Berthier, (Ann. de Chim. et de Phys. t. xxxii. p. 248,)

Potash and Soda	16·8	in which	3·42	parts must be oxygen.
Lime	29·5	,,	8·20 ,,	,,
Magnesia . .	3·2	,,	1·20 ,,	,,
	49·5		12·82	

Only part of the potash and soda in these ashes was in combination with organic acids ; the remainder was in the form of sulphates, phosphates, and chlorides. One hundred parts of the ashes contain 3·1 sulphuric acid, 4·2 phosphoric acid, and 0·3 hydrochloric acid, which together neutralize a quantity of base containing 1·20 oxygen. This number therefore must be subtracted from 12·82. The remainder 11·62 indicates the quantity of oxygen in the alkaline bases, combined with organic acids in the firwood of Allevard.

The firwood of Norway contained in 100 parts*,—

Potash . . .	14·1	of which	2·4. parts would be oxygen.
Soda . . .	20·7	,,	5·3 ,,	,,
Lime . . .	12·3	,,	3·45 ,,	,,
Magnesia . .	4·35	,,	1·69 ,,	,,
	51·45		12·84	

* This calculation is exact only in the case where the quantity of ashes is equal in weight for a given quantity of wood; the difference

And if the quantity of oxygen of the bases in combination with sulphuric and phosphoric acid, viz. 1·37, be again subtracted from 12·84, 11·47 parts remain as the amount of oxygen contained in the bases which were in combination with organic acids.

These remarkable approximations cannot be accidental; and if further examinations confirm them in other kinds of plants, no other explanation than that already given can be adopted.

It is not known in what form silica, manganese, and oxide of iron, are contained in plants; but we are certain that potash, soda, and magnesia, can be extracted from all parts of their structure in the form of salts of organic acids. The same is the case with lime, when not present as insoluble oxalate of lime. It must here be remembered, that in plants yielding oxalic acid, the acid and potash never exist in the form of a neutral or quadruple salt, but always as a double acid salt, on whatever soil they may grow. The potash in grapes, also, is more frequently found as an acid salt, viz. cream of tartar (bitartrate of potash), than in the form of a neutral compound. As these acids and bases are never absent from plants, and as even the form in which they present themselves is not subject to change, it may be affirmed that they exercise an important influence on the development of the fruits and seeds, and also on many other functions of the nature of which we are at present ignorant.

The quantity of alkaline bases existing in a plant also depends evidently on this circumstance of their existing only in the form of acid salts,—for the capacity of satu-

cannot, however, be admitted to be so great as to change sensibly the above proportions. Berthier has not mentioned the proportion of ashes contained in the wood.

ration of an acid is constant; and when we see oxalate
of lime in the lichens occupying the place of woody fibre
which is absent, we must regard it as certain that the
soluble organic salts are destined to fulfil equally import-
ant though different functions, so much so that we could
not conceive the complete development of a plant without
their presence, that is, without the presence of their acids,
and consequently of their bases.

From these considerations we must perceive, that exact
and trustworthy examinations of the ashes of plants of
the same kind growing upon different soils would be of
the greatest importance to vegetable physiology, and
would decide whether the facts above mentioned are the
results of an unchanging law for each family of plants,
and whether an invariable number can be found to express
the quantity of oxygen which each species of plant con-
tains in the bases united with organic acids. In all pro-
bability such inquiries will lead to most important results;
for it is clear that if the production of a certain unchang-
ing quantity of an organic acid is required by the peculiar
nature of the organs of a plant, and is necessary to its
existence, then potash or lime must be taken up by it
in order to form salts with this acid; that if these do not
exist in sufficient quantity in the soil, other bases must
supply their place; and that the progress of a plant must
be wholly arrested when none are present.

Seeds of the *Salsola Kali*, when sown in common
garden soil, produce a plant containing both potash and
soda; while the plants grown from the seeds of this
contain only salts of potash, with mere traces of muriate
of soda. (Cadet.)

The examples cited above, in which the quantity of
oxygen contained in the bases was shown to be the same,

lead us to the legitimate conclusion that the development of certain plants is not retarded by the substitution of the bases contained in them. But it was by no means inferred that any one base could replace all the others which are found in a plant in its normal condition. On the contrary, it is known that certain bases are indispensable for the growth of a plant, and these could not be substituted without injuring its development. Our inference has been drawn from certain plants, which can bear without injury this substitution; and it can only be extended to those plants which are in the same condition. It will be shown afterwards that corn or vines can only thrive on soils containing potash, and that this alkali is perfectly indispensable to their growth. Experiments have not been sufficiently multiplied so as to enable us to point out in what plants potash or soda may be replaced by lime or magnesia; we are only warranted in affirming that such substitutions are in many cases common. The ashes of various kinds of plants contain very different quantities of alkaline bases, such as potash, soda, lime, or magnesia. When lime exists in the ashes in large proportion, the quantity of magnesia is diminished, and in like manner according as the latter increases the lime or potash decreases. In many kinds of ashes not a trace of magnesia can be detected.

The existence of vegetable alkalies in combination with organic acids gives great weight to the opinion that alkaline bases in general are connected with the development of plants.

If potatoes are grown where they are not supplied with earth, the magazine of inorganic bases, (in cellars, for example,) a true alkali, called Solanin, of very poisonous nature, is formed in the sprouts which extend

towards the light, while not the smallest trace of such
substance can be discovered in the roots, herbs, blossoms
or fruits of potatoes grown in fields. (Otto.) In all th
species of the *Cinchona*, kinic acid is found; but th
quantity of quinina, cinchonina, and lime, which the
contain is most variable. From the fixed bases in th
products of incineration, however, we may estimate prett
accurately the quantity of the peculiar organic bases
A maximum of the first corresponds to a minimum of th
latter, as must necessarily be the case if they mutuall
replace one another according to their equivalents. W
know that different kinds of opium contain meconic aci
in combination with very different quantities of narcotine
morphia, codeia, &c., the quantity of one of these alka
loids diminishing on the increase of the others. Thu
the smallest quantity of morphia is accompanied by
maximum of narcotina. Not a trace of meconic acid
can be discovered in many kinds of opium, but there i
not on this account an absence of acid, for the meconic i
here replaced by sulphuric acid. Here, also, we hav
an example of what has been before stated, for in thos
kinds of opium where both these acids exist, they ar
always found to bear a certain relative proportion to on
another.   Attention to these facts must be very importan
in the selection of soils destined for the cultivation c
plants which yield the vegetable alkaloids.

Now if it be found, as appears to be the case in th
juice of poppies, that an organic acid may be replaced b
an inorganic, without impeding the growth of a plant, w
must admit the probability of this substitution taking plac

* Robiquet did not obtain a trace of meconate of lime from 300 lbs.
opium, whilst in other kinds the quantity was very considerable. An
de Chim. liii. p. 425.

in a much higher degree in the case of the inorganic bases.

When roots find their more appropriate base in sufficient quantity, they will take up less of another.

These phenomena do not show themselves so frequently in cultivated plants, because they are subjected to special external conditions for the purpose of the production of particular constituents or particular organs.

When the soil, in which a white hyacinth is growing in a state of blossom, is sprinkled with the juice of the *Phytolacca decandra*, the white blossoms assume in one or two hours a red colour, which again disappears after a few days under the influence of sunshine, and they become white and colourless as before*. The juice in this case evidently enters into all parts of the plant, without being at all changed in its chemical nature, or without its presence being apparently either necessary or injurious. But this condition is not permanent, and when the blossoms have again become colourless, none of the colouring matter remains; and if it should occur that any of its elements were adapted for the purposes of nutrition of the plant, then these alone would be retained, whilst the rest would be excreted in an altered form by the roots.

Exactly the same thing must happen when we sprinkle a plant with a solution of chloride of potassium, nitre, or nitrate of strontia; they will enter into the different parts of the plant, just as the coloured juice mentioned above, and will be found in its ashes if it should be burnt at this period. Their presence is merely accidental; but no conclusion can be hence deduced against the necessity of

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* Biot, in the Comptes rendus des Séances de l'Académie des Sciences, à Paris, 1 er Sémestre, 1837, p. 12.

the presence of other bases in plants.   The experiments
of Macaire-Princep have shown, that plants made to
vegetate with their roots in a weak solution of acetate of
lead, and then in rain-water, yield to the latter all the
salt of lead which they had previously absorbed.   They
return, therefore, to the soil all matters which are unne-
cessary to their existence.   Again, when a plant, freely
exposed to the atmosphere, rain, and sunshine, is
sprinkled with a solution of nitrate of strontia, the salt
is absorbed, but it is again separated by the roots and
removed further from them by every shower of rain,
which moistens the soil, so that at last not a trace of it
is to be found in the plant.

Let us consider the composition of the ashes of two
fir-trees as analysed by an acute and most accurate
chemist.   One of these grew in Norway, on a soil the
constituents of which never changed, but to which solu-
ble salts, and particularly common salt, were conveyed
in great quantity by rain-water.   How did it happen that
its ashes contained no appreciable trace of salt, although
we are certain that its roots must have absorbed it after
every shower?

We can explain the absence of salt in this case by
means of the direct and positive observations referred to,
which have shown that plants have the power of return-
ing to the soil all substances unnecessary to their exist-
ence ; and the conclusion to which all the foregoing facts
lead us, when their real value and bearing are appre-
hended, is that the alkaline bases existing in the ashes
of plants must be necessary to their growth, since if this
were not the case they would not be retained.

The perfect development of a plant, according to this
view, is dependent on the presence of alkalies or alkaline

earths; for when these substances are totally wanting
its growth will be arrested, and when they are only defi-
cient it must be impeded.

In order to apply these remarks, let us compare two
kinds of trees, the wood of which contains unequal quan-
tities of alkaline bases, and we shall find that one of
these grows luxuriantly in several soils upon which the
others are scarcely able to vegetate. For example,
10,000 parts of oak-wood yield 250 parts of ashes, the
same quantity of fir-wood only 83, of linden-wood 500,
of rye 440, and of the herb of the potato-plant 1500 parts*.

Firs and pines find a sufficient quantity of alkalies in
granitic and barren sandy soils in which oaks will not
grow; and wheat thrives in soils favourable for the lin-
den-tree, because the bases which are necessary to bring
it to complete maturity, exist there in sufficient quantity.
The accuracy of these conclusions, so highly important
to agriculture and to the cultivation of forests, can be
proved by the most evident facts.

All kinds of grasses, the *Equisetaceæ*, for example,
contain in the outer parts of their leaves and stalk
a large quantity of silicic acid and potash in the form
of acid silicate of potash. The proportion of this salt
does not vary perceptibly in the soil of corn-fields,
because it is again conveyed to them as manure in the
form of putrifying straw. But this is not the case in
a meadow, and hence we never find a luxuriant crop of
grass† on sandy and calcareous soils, which contain little

* Berthier, Annales de Chimie et de Physique, t. xxx. p. 248.

† It would be of importance to examine what alkalies are contained in
the ashes of the sea-shore plants which grow in the humid hollows of
downs, and especially in those of the millet-grass. If potash is not found
in them, it must certainly be replaced by soda as in the *Salsola*, or by
lime as in the *Plumbaginea*.

potash, evidently because one of the constituents indispensable to the growth of the plants is wanting. Soils formed from basalt, grauwacke, and porphyry, are, *cæteris paribus,* the best for meadow-land, on account of the quantity of potash which enters into their composition. The potash abstracted by the plants is restored during the annual irrigation. The potash contained in the soil itself is inexhaustible in comparison with the quantity removed by plants. But when we increase the crop of grass in a meadow by means of gypsum, we remove a greater quantity of potash with the hay than can under the same circumstances be restored. Hence it happens that, after the lapse of several years, the crops of grass on the meadows manured with gypsum diminish, owing to the deficiency of potash. But if the meadow be strewed from time to time with wood-ashes, even with the lixiviated ashes which have been used by soap-boilers, (in Germany much soap is made from the ashes of wood,) then the grass thrives as luxuriantly as before. The ashes are only a means of restoring the potash.

A harvest of grain is obtained every thirty or forty years from the soil of the Luneburg heath, by strewing it with the ashes of the heath-plants (*Erica vulgaris*) which grow on it. These plants during the long period just mentioned collect the potash and soda, which are conveyed to them by rain-water; and it is by means of these alkalies that oats, barley, and rye, to which they are indispensable, are enabled to grow on this sandy heath.

The woodcutters in the vicinity of Heidelberg have the privilege of cultivating the soil for their own use, after felling the trees used for making tan. Before sowing the land thus obtained, the branches, roots, and leaves,

are in every case burned, and the ashes used as a manure, which is fouhd to be quite indispensable for the growth of the grain. The soil itself upon which the oats grow in this district consists of sandstone ; and although the trees find in it a quantity of alkaline earths sufficient for their own sustenance, yet in its ordinary condition it is incapable of producing grain.

The most decisive proof of the use of strong manure was obtained at Bingen (a town on the Rhine), where the produce and development of vines were highly increased by manuring them with such substances as shavings of horn, &c. ; but after some years the formation of the wood and leaves decreased to the great loss of the possessor, to such a degree that he has long had cause to regret his departure from the usual methods. By the manure employed by him, the vines had been too much hastened in their growth ; in two or three years they had exhausted the potash in the formation of their fruit, leaves, and wood, so that none remained for the future crops, his manure not having contained any potash.

There are vineyards on the Rhine the plants of which are above a hundred years old, and all of these have been cultivated by manuring them with cow-dung, a manure containing a large proportion of potash, although very little nitrogen. All the potash, in fact, which is contained in the food consumed by a cow is again immediately discharged in its excrements.

The experience of a proprietor of land in the vicinity of Gottingen offers a most remarkable example of the incapability of a soil to produce wheat or grasses in general, when it fails in any one of the materials necessary to their growth. In order to obtain potash, he planted his whole land with wormwood, the ashes of which are well known

to contain a large proportion of the carbonate of that
alkali. The consequence was, that he rendêred his land
quite incapable of bearing grain for many years, in con-
sequence of having entirely deprived the soil of its
potash.

The leaves and small branches of trees contain the
most potash; and the quantity of them which is annually
taken from a wood, for the purpose of being employed as
litter*, contain more of that alkali than all the old wood
which is cut down. The bark and foliage of oaks, for
example, contain from 6 to 9 per cent. of this alkali; the
needles of firs and pines, 8 per cent.

With every 2650 lbs. of fir-wood which are yearly
removed from an acre of forest, only from 0·114 to 0·53
lbs. of alkalies are abstracted from the soil, calculating the
ashes at 0·83 per cent. The moss, however, which covers
the ground, and of which the ashes are known to contain
so much alkali, continues uninterrupted in its growth,
and retains that potash on the surface, which would other-
wise so easily penetrate with the rain through the sandy
soil. By its decay, an abundant provision of alkalies is
supplied to the roots of the trees, and a fresh supply is
rendered unnecessary.

The supposition of alkalies, metallic oxides, or in-
organic matter in general, being produced by plants, is
entirely refuted by these well-authenticated facts.

It is thought very remarkable, that those plants of the
grass tribe, the seeds of which furnish food for man,

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* [This refers to a custom some time since very prevalent in Germany,
although now discontinued. The leaves and small twigs of trees were
gleaned from the forests by poor people, for the purpose of being used
as litter for their cattle. The trees, however, were found to suffer so
much in consequence, that their removal is now strictly prohibited.
The cause of the injury was that stated in the text.—ED.]

follow him like the domestic animals. But saline plants
seek the sea-shore or saline springs, and the Chenopo-
dium the dunghill from similar causes. Saline plants
require common salt, and the plants which grow only on
dunghills need ammonia and nitrates, and they are
attracted whither these can be found, just as the dung-fly
is to animal excrements. So likewise none of our corn-
plants can bear perfect seeds, that is, seeds yielding flour,
without a large supply of phosphate of magnesia and
ammonia, substances which they require for their matu-
rity. And hence, these plants grow only in a soil where
these three constituents are found combined, and no soil is
richer in them than those where men and animals dwell
together; where the urine and excrements of these are
found corn-plants appear, because their seeds cannot
attain maturity unless supplied with the constituents of
those matters.

When we find sea-plants near our salt-works, several
hundred miles distant from the sea, we know that their
seeds have been carried there in a very natural manner,
namely, by wind or birds, which have spread them over
the whole surface of the earth, although they grow only
in those places in which they find the conditions essential
to their life.

Numerous small fish, of not more than two inches in
length *(Gasterosteus aculeatus)*, are found in the salt-pans
of the graduating house at Nidda (a village in Hesse
Darmstadt). No living animal is found in the salt-pans
of Neuheim, situated about 18 miles from Nidda; but
the water there contains so much carbonic acid and lime,
that the walls of the graduating house are covered with
stalactites. Hence the eggs conveyed to this place by

birds do not find the conditions necessary for their development, which they found in the former place*.

How much more wonderful and inexplicable does it appear, that bodies which remain fixed in the strong heat of a fire, have under certain conditions the property of volatilizing and, at ordinary temperatures, of passing into a state, of which we cannot say whether they have really assumed the form of a gas or are dissolved in one ! Steam or vapours in general have a very singular influence in causing the volatilization of such bodies, that is, of causing them to assume the gaseous form. A liquid during evaporation communicates the power of assuming the same state in a greater or less degree to all substances dissolved in it, although they do not of themselves possess that property.

Boracic acid is a substance which is completely fixed in the fire; it suffers no change of weight appreciable by the most delicate balance, when exposed to a white heat, and, therefore, it is not volatile. Yet its solution in water

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* The itch-insect *(Acarus Scabiei)* is considered by Burdach as the production of a morbid condition, so likewise lice in children ; the original generation of the fresh-water muscle *(mytilus)* in fish-ponds, of sea-plants in the vicinity of salt-works, of nettles and grasses, of fish in pools of rain, of trout in mountain streams, &c., is, according to the same natural philosopher, not impossible. A soil consisting of crumbled rocks, decayed vegetables, rain and salt water, &c., is here supposed to possess the power of generating shell-fish, trout, and saltwort *(salicornia).* All inquiry is arrested by such opinions, when propagated by a teacher who enjoys a merited reputation, obtained by knowledge and hard labour. These subjects, however, have hitherto met with the most superficial observation, although they well merit strict investigation. The dark, the secret, the mysterious, the enigmatic, is, in fact, too seducing for the youthful and philosophic mind, which would penetrate the deepest depths of nature, without the assistance of the shaft or ladder of the miner. This is poetry, but not sober philosophical inquiry.

cannot be evaporated by the gentlest heat, without the escape of a sensible quantity of the acid with the steam. Hence it is that a loss is always experienced in the analysis of minerals containing this acid, when liquids in which it is dissolved are evaporated. The quantity of boracic acid which escapes with a cubic foot of steam, at the temperature of boiling water, cannot be detected by our most sensible re-agents; and nevertheless the many hundred tons annually brought from Italy as an article of commerce, are procured by the uninterrupted accumulation of this apparently inappreciable quantity. The hot steam which issues from the interior of the earth is allowed to pass through cold water in the lagoons of Castel Nuova and Cherchiago; in this way the boracic acid is gradually accumulated, till at last it may be obtained in crystals by the evaporation of the water. It is evident, from the temperature of the steam, that it must have come out of depths in which human beings and animals never could have lived, and yet it is very remarkable and highly important that ammonia is never absent from it. In the large works in Liverpool, where natural boracic acid is converted into borax, many hundred pounds of sulphate of ammonia are obtained at the same time.

This ammonia has not been produced by the animal organism, it existed before the creation of human beings; it is a part, a primary constituent, of the globe itself.

The experiments instituted under Lavoisier's guidance by the *Direction des Poudres et Salpêtres*, have proved that during the evaporation of the saltpetre ley, the salt volatilizes with the water, and causes a loss which could not before be explained. It is known also, that in sea-storms, leaves of plants in the direction of the wind are covered with crystals of salt, even at the distance of from 20 to 30

miles from the sea. But it does not require a storm to
cause the volatilization of the salt, for the air hanging over
the sea always contains enough of this substance to make
a solution of nitrate of silver turbid, and every breeze must
carry this away.   Now, as thousands of tons of sea-water
annually evaporate into the atmosphere, a corresponding
quantity of the salts dissolved in it, viz. of common salt,
chloride of potassium, magnesia, and the remaining con-
stituents of the sea-water, will be conveyed by wind to the
land.

This volatilization is a source of considerable loss in
salt-works, especially where the proportion of salt in the
water is not large.   This has been completely proved
at the salt-works of Nauheim, by the very intelligent
director of that establishment, M. Wilhelmi.   He hung a
plate of glass between two evaporating houses, which
were about 1200 paces distant from each other, and found
in the morning, after the drying of the dew, that the
glass was covered with crystals of salt on one or the
other side, according to the direction of the wind.

By the continual evaporation of the sea, its salts* are

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* According to Marcet, sea-water contains in 1000 parts,

26·660 Chloride of Sodium.
4·660 Sulphate of Soda.
1·232 Chloride of Potassium.
5·152 Chloride of Magnesium.
0·153 Sulphate of Lime.

According to M'Clemm, the water of the North Sea contains in 1000 parts,

24·84 Chloride of Sodium.
2·42 Chloride of Magnesium.
2·06 Sulphate of Magnesia.
1·35 Chloride of Potassium.
1·20 Sulphate of Lime.

In addition to these constituents, it also contains inappreciable quantities
of carbonate of lime, magnesia, iron, manganese, phosphate of lime, iodides
and bromides, silica, sulphuretted hydrogen, and organic matter, together
with ammonia and carbonic acid. (Liebig's *Annalen der Chemie*,
Bd. xxxvii. s. 3.)

spread over the whole surface of the earth; and being subsequently carried down by the rain, furnish to the vegetation those salts necessary to its existence.   This is the origin of the salts found in the ashes of plants, in those cases where the soil could not have yielded them.

In a comprehensive view of the phenomena of nature, we have no scale for that which we are accustomed to name, small or great; all our ideas are proportioned to what we see around us, but how insignificant are they in comparison with the whole mass of the globe! that which is scarcely observable in a confined district appears inconceivably large when regarded in its extension through unlimited space.   The atmosphere contains only a thousandth part of its weight of carbonic acid; and yet small as this proportion appears, it is quite sufficient to supply the whole of the present generation of living beings with carbon for a thousand years, even if it were not renewed. Sea-water contains $\frac{1}{12420}$ of its weight of carbonate of lime; and this quantity, although scarcely appreciable in a pound, is the source from which myriads of marine mollusca and corals are supplied with materials for their habitations.

Whilst the air contains only from 4 to 6 ten-thousandth parts of its volume of carbonic acid, sea-water contains 100 times more, (10,000 volumes of sea-water contain 620 volumes of carbonic acid—Laurent, Bouillon, Lagrange). Ammonia * is also found in this water, so that the same conditions which sustain living beings on the land are combined in this medium, in which a whole world of other plants and animals exist.

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* When the solid saline residue obtained by the evaporation of sea-water is heated in a retort to redness, a sublimate of sal-ammoniac is obtained.—MARCET.

The roots of plants are constantly engaged in collecting from the rain those alkalies which formed part of the sea-water, and also those of the water of springs, which penetrates the soil. Without alkalies and alkaline bases most plants could not exist, and without plants the alkalies would disappear gradually from the surface of the earth.

When it is considered that sea-water contains less than one-millionth of its own weight of iodine, and that all combinations of iodine with the metallic bases of alkalies are highly soluble in water, some provision must necessarily be supposed to exist in the organization of seaweed and the different kinds of Fuci, by which they are enabled during their life to extract iodine in the form of a soluble salt from sea-water, and to assimilate it in such a manner, that it is not again restored to the surrounding medium. These plants are collectors of iodine, just as land-plants are of alkalies ; and they yield us this element, in quantities such as we could not otherwise obtain from the water without the evaporation of whole seas.

We take it for granted, that the sea-plants require metallic iodides for their growth, and that their existence is dependent on the presence of those substances. With equal justice, then, we conclude, that the alkalies and alkaline earths, always found in the ashes of land-plants, are likewise necessary for their development.

CHAPTER VII.

THE ART OF CULTURE.

The conditions necessary for the life of all vegetables have been considered in the preceding part of the work. Carbonic acid, ammonia, and water, yield elements for all the organs of plants. Certain inorganic substances—salts and metallic oxides—serve peculiar functions in their organism, and many of them must be viewed as essential constituents of particular parts.

The atmosphere and the soil offer the same kind of nourishment to the leaves and roots. The former contains a comparatively inexhaustible supply of carbonic acid and ammonia; the latter, by means of its humus, generates constantly fresh carbonic acid, whilst, during the winter, rain and snow introduce into the soil a quantity of ammonia, sufficient for the development of the leaves and blossoms.

The complete, or it may be said, the absolute insolubility in cold water of vegetable matter in progress of decay, (humus,) appears on closer consideration to be a most wise arrangement of nature. For if humus possessed even a smaller degree of solubility than that ascribed to the substance called humic acid, it must be dissolved by rain-water. Thus, the yearly irrigation of meadows, which lasts for several weeks, would remove a great part of it from the ground, and a heavy and continued rain

would impoverish a soil. But it is soluble only when combined with oxygen; it can be taken up by water, therefore, only as carbonic acid.

When kept in a dry place, humus may be preserved for centuries; but when moistened with water, it converts the surrounding oxygen into carbonic acid. As soon as the action of the air ceases, that is, as soon as it is deprived of oxygen, the humus suffers no further change. Its decay proceeds only when plants grow in the soil containing it; for they absorb by their roots the carbonic acid as it is formed. The soil receives again from living plants the carbonaceous matter it thus loses, so that the proportion of humus in it does not decrease.

The stalactitic caverns in Franconia, and those in the vicinity of Baireuth, and Streitberg, lie beneath a fertile arable soil; the abundant decaying vegetables or humus in this soil, being acted on by moisture and air, constantly evolve carbonic acid, which is dissolved by the rain. The rain-water thus impregnated permeates the porous limestone, which forms the walls and roofs of the caverns, and dissolves in its passage as much carbonate of lime as corresponds to the quantity of carbonic acid contained in it. Water and the excess of carbonic acid evaporate from this solution when it has reached the interior of the caverns, and the limestone is deposited on the walls and roofs in crystalline crusts of various forms. There are few spots on the earth where so many circumstances favourable to the production of humate of lime are combined, if the humus actually existed in the soil in the form of humic acid. Decaying vegetable matter, water, and lime in solution, are brought together, but the stalactites formed contain no trace of vegetable matter, and no humic acid; they are of a glistening white or yellowish colour, and in

part transparent, like calcareous spar, and may be heated
to redness without becoming black.

The subterranean vaults in the old castles near the
Rhine, the " Bergstrass," and Wetherau, are constructed
of sandstone, granite, or basalt, and present appearances
similar to the limestone caverns. The roofs of these
vaults or cellars are covered externally to the thickness of
several feet with vegetable mould, which has been formed
by the decay of plants. The rain falling upon them sinks
through the earth, and dissolves the mortar by means of
the carbonic acid derived from the mould ; and this solu-
tion evaporating in the interior of the vaults, covers them
with small thin stalactites, which are quite free from
humic acid.

In such a filtering apparatus, built by the hand of
nature, we have placed before us experiments which have
been continued for a hundred or a thousand years. Now,
if water possessed the power of dissolving a hundred-
thousandth part of its own weight of humic acid or
humate of lime, and humic acid were present, we should
find the inner surface of the roofs of these vaults and
caverns covered with these substances ; but we cannot
detect the smallest trace of them. There could scarcely
be found a more clear and convincing proof of the
absence of the humic acid of chemists in common vege-
table mould.

The common view, which has been adopted respecting
the *modus operandi* of humic acid, does not afford any
explanation of the following phenomenon : —A very small
quantity of humic acid dissolved in water gives it a yellow
or brown colour. Hence it would be supposed that a
soil would be more fruitful in proportion as it was capable
of giving this colour to water, that is, of yielding it humic

acid. But it is very remarkable that plants do not thrive
in such a soil, and that all manure must have lost this
property before it can exercise a favourable influence
upon their vegetation.   Water from barren peat soils
and marshy meadows, upon which few plants flourish,
contains much of this humic acid; but all agriculturists
and gardeners agree that the most suitable and best
manure for plants is that which has completely lost the
property of giving a colour to water.

The soluble substance, which gives to water a brown
colour, is a product of the putrefaction of all animal and
vegetable matters; its formation is an evidence that there
is not oxygen sufficient to begin, or at least to complete
the decay.   The brown solutions containing this sub-
stance are decolourised in the air by absorbing oxygen,
and a black coaly matter precipitates—the substance
named "coal of humus."   Now if a soil were impreg-
nated with this matter, the effect on the roots of plants
would be the same as that of entirely depriving the soil
of oxygen; plants would be as little able to grow in such
ground as they would if hydrated protoxide of iron were
mixed with the soil. Indeed some barren soils have been
found to owe their sterility to this very cause.   The sul-
phate of protoxide of iron (copperas), which forms a
constituent of these soils, possesses a powerful affinity
for oxygen, and consequently prevents the absorption of
that gas by the roots of plants in its vicinity*.   All
plants die in soils and water which contain no oxygen;

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* The most obvious method of removing this salt from soils in which
it may be contained is to manure the land with lime. The lime unites
with the sulphuric acid and liberates the protoxide of iron, which
absorbs oxygen with much rapidity, and is converted into the peroxide of
iron. This conversion is accelerated by giving free access to the air,
that is, by loosening the soil.

absence of air acts exactly in the same manner as an
excess of carbonic acid. Stagnant water on a marshy
soil excludes air, but a renewal of water has the same
effect as a renewal of air, because water contains it in
solution. If the water is withdrawn from a marsh, free
access is given to the air, and the marsh is changed into
a fruitful meadow.

In a soil to which the air has no access, or at most but
very little, the remains of animals and vegetables do not
decay, for they can only do so when freely supplied with
oxygen; but they undergo putrefaction, for which air is
present in sufficient quantity. Putrefaction is known to
be a most powerful deoxidising process, the influence of
which extends to all surrounding bodies, even to the
roots and the plants themselves. All substances from
which oxygen can be extracted yield it to putrefying
bodies; yellow oxide of iron passes into the state of black
oxide, sulphate of iron into sulphuret of iron, &c.

The frequent renewal of air by ploughing, and the
preparation of the soil, especially its contact with alka-
line metallic oxides, the ashes of brown coal, burnt lime
or limestone, change the putrefaction of its organic con-
stituents into a pure process of oxidation; and from the
moment at which all the organic matter existing in a soil
enters into a state of oxidation or decay, its fertility is
increased. The oxygen is no longer employed for the
conversion of the brown soluble matter into the insoluble
coal of humus, but serves for the formation of carbonic
acid. This change takes place very slowly, and in some
instances the oxygen is completely excluded by it; and
whenever this happens, the soil loses its fertility. Thus,
in the vicinity of Salzhausen (a village in Hesse Darm-
stadt, famed for its mineral springs), upon a meadow

called Grünschwalheimer, unfruitful spots are seen here
and there covered with a yellow grass.   If a hole be
bored from twenty to twenty-five feet deep in one of these
spots, carbonic acid is emitted from it with such violence
that the noise made by the escape of the gas may be dis-
tinctly heard at the distance of several feet.   Here the
carbonic acid rising to the surface displaces completely
all the air, and consequently all the oxygen, from the
soil; and without oxygen neither seeds nor roots can
be developed ; a plant will not vegetate in pure nitrogen
or carbonic acid gas.

Humus supplies young plants with nourishment by
the roots, until their leaves are matured sufficiently to act
as exterior organs of nutrition; its quantity heightens the
fertility of a soil by yielding more nourishment in this
first period of growth, and consequently by increasing
the number of organs of atmospheric nutrition.   Those
plants which receive their first food from the substance
of their seeds, such as bulbous plants, could completely
dispense with humus; its presence is useful only in so
far as it increases and accelerates their development, but it
is not necessary—indeed, an excess of it at the commence-
ment of their growth is in a certain measure injurious.

The amount of food which young plants can take from
the atmosphere in the form of carbonic acid and ammonia
is limited; they cannot assimilate more than the air con-
tains.   Now, if the quantity of their stems, leaves, and
branches has been increased by the excess of food yielded
by the soil at the commencement of their development,
they will require for the completion of their growth, and
for the formation of their blossoms and fruits, more
nourishment from the air than it can afford, and conse-
quently they will not reach maturity.   In many cases the

nourishment afforded by the air under these circumstances suffices only to complete the formation of the leaves, stems, and branches. The same result then ensues as when ornamental plants are transplanted from the pots in which they have grown to larger ones, in which their roots are permitted to increase and multiply. All their nourishment is employed for the increase of their roots and leaves; they spring, as it is said, into an herb or weed, but do not blossom. When, on the contrary, we take away part of the branches, and of course their leaves with them, from dwarf trees, since we thus prevent the development of new branches, an excess of nutriment is artificially procured for the trees, and is employed by them in the increase of the blossoms and enlargement of the fruit. It is to effect this purpose that vines are pruned.

A new and peculiar process of vegetation ensues in all perennial plants, such as shrubs, fruit, and forest trees, after the complete maturity of their fruit. The stem of annual plants at this period of their growth becomes woody, and their leaves change in colour. The leaves of trees and shrubs, on the contrary, remain in activity until the commencement of the winter. The formation of the layers of wood progresses, the wood becomes harder and more solid, but after August the leaves form no more wood; all the carbonic acid which the plants now absorb is employed for the production of nutritive matter for the following year: instead of woody fibre, starch is formed, and is diffused through every part of the plant by the autumnal sap (sève d'Août)*. According to the observations of M. Heyer, the starch thus depo-

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* Hartig, in Erdmann und Schweigger-Seidels Journal, V. 217. 1835.

sited in the body of the tree can be recognised in its
known form by the aid of a good microscope: The barks
of several aspens and pine-trees* contain so much of this
substance, that it can be extracted from them as from
potatoes by trituration with water. It exists also in the
roots and other parts of perennial plants. A very
early winter, or sudden change of temperature, pre-
vents the formation of this provision for the follow-
ing year; the wood, as in the case of the vine-stock,
does not ripen, and its growth is in the next year very
limited.

From the starch thus accumulated, sugar and gum are
produced in the succeeding spring, while from the gum
those constituents of the leaves and young sprouts which
contain no nitrogen are in their turn formed. After
potatoes have germinated, the quantity of starch in them
is found diminished. The juice of the maple-tree ceases
to be sweet from the loss of its sugar when its buds,
blossoms, and leaves attain their maturity.

The branch of a willow, which contains a large quan-
tity of granules of starch in every part of its woody sub-
stance, puts forth both roots and leaves in pure distilled
rain-water; but in proportion as it grows, the starch
disappears, it being evidently exhausted for the formation
of the roots and leaves. In the course of these experi-
ments, M. Heyer made the interesting observation, that
such branches when placed in snow-water (which con-
tains ammonia) produced roots three or four times longer
than those which they formed in pure distilled water, and
that this pure water remained clear, while the rain-water
gradually acquired a yellow colour.

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* It is well known that bread is made from the bark of pines in
Sweden during famines.

Upon the blossoming of the sugar-cane, likewise, part of the sugar disappears ; and it has been ascertained, that the sugar does not accumulate in the beet-root until after the leaves are completely formed.

Much attention has recently been drawn to the fact that the produce of potatoes may be much increased by plucking off the blossoms from the plants producing them, a result quite consistent with theory.   This important observation has been completely confirmed by M. Zeller, the director of the Agricultural Society at Darmstadt.   In the year 1839, two fields of the same size, lying side by side, and manured in the same manner, were planted with potatoes.   When the plants had flowered, the blossoms were removed from those in one field, while those in the other field were left untouched.   The former produced 47 bolls, the latter only 37 bolls.

These well-authenticated observations remove every doubt as to the part which sugar, starch, and gum play in the development of plants ; and it ceases to be enigmatical, why these three substances exercise no influence on the growth or process of nutrition of a matured plant, when supplied to them as food.

The accumulation of starch in plants during the autumn has been compared, although certainly erroneously, to the fattening of hibernating animals before their winter sleep ; but in these animals every vital function, except the process of respiration, is suspended, and they only require, like a lamp slowly burning, a substance rich in carbon and hydrogen to support the process of combustion in the lungs.   On their awaking from their torpor in the spring, the fat has disappeared, but has not served as nourishment.   It has not caused the least increase in any part of their body, neither has it changed the quality

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of any of their organs. With nutrition, properly so
called, the fat in these animals has not the least con-
nexion.

The annual plants form and collect their future nourish-
ment in the same way as the perennial; they store it in
their seeds in the form of vegetable albumen, starch, and
gum, which are used by the germs for the formation of
their leaves and first radicle fibres. The proper nutri-
tion of the plants, their increase in size, begins after these
organs are formed.

Every germ and every bud of a perennial plant is the
engrafted embryo of a new individual, while the nutri-
ment accumulated in the stem and roots, corresponds to
the albumen of the seeds.

Nutritive matters are, correctly speaking, those sub-
stances which, when presented from without, are capable
of sustaining the life and all the functions of an organism,
by furnishing to the different parts of plants the materials
for the production of their peculiar constituents.

In animals, the blood is the source of the material of
the muscles and nerves; by one of its component parts,
the blood supports the process of respiration, by others,
the peculiar vital functions; every part of the body is
supplied with nourishment by it, but its own production
is a special function, without whioh we could not conceive
life to continue. If we destroy the activity of the organs
which produce it, or if we inject the blood of one animal
into the veins of another, at all events if we carry this
beyond certain limits, death is the consequence.

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; conse-

quently, 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.

Other substances must be present in a plant, besides the starch, sugar, and gum, if these are to take part in the development of the germ, leaves, and first radicle fibres. There is no doubt that a grain of wheat contains within itself the component parts of the germ and of the radicle fibres, and, we must suppose, exactly in the proportion necessary for their formation. These component parts are starch and gluten; and it is evident that neither of them alone, but that both simultaneously assist in the formation of the root, for they both suffer changes under the action of air, moisture, and a suitable temperature. The starch is converted into sugar, and the gluten also assumes a new form, and both acquire the capability of being dissolved in water, and of thus being conveyed to every part of the plant. Both the starch and the gum are completely consumed in the formation of the first part of the roots and leaves; an excess of either could not be used in the formation of leaves, or in any other way.

The conversion of starch into sugar during the germination of grain is ascribed to a vegetable principle called *diastase,* which is generated during the act of commencing germination. But this mode of transformation can also be effected by gluten, although it requires a longer time. Seeds, which have germinated, always contain much more diastase than is necessary for the conversion of their starch into sugar, for five parts by weight of starch can be converted into sugar by one part of malted barley. This excess of diastase can by no means be regarded as accidental, for, like the starch, it aids in the formation of the

first organs of the young plant, and disappears with the sugar; diastase contains nitrogen and furnishes the elements of vegetable albumen.

Carbonic acid, water, and ammonia, are the food of fully-developed plants; starch, sugar, and gum, serve, when accompanied by an azotised substance, to sustain the embryo, until its first organs of nutrition are unfolded. The nutrition of a fœtus and development of an egg proceed in a totally different manner from that of an animal which is separated from its parent; the exclusion of air does not endanger the life of the fœtus, but would certainly cause the death of the independent animal. In the same manner, pure water is more advantageous to the growth of a young plant, than that containing carbonic acid, but after a month the reverse is the case.

The formation of sugar in maple-trees does not take place in the roots, but in the woody substance of the stem. The quantity of sugar in the sap augments until it reaches a certain height in the stem of the plant, above which point it remains stationary.

Just as germinating barley produces a substance which, in contact with starch, causes it to lose its insolubility and to become sugar, so in the roots of the maple, at the commencement of vegetation, a substance must be formed, which, being dissolved in water, permeates the wood of the trunk, and converts into sugar the starch, or whatever it may be, which it finds deposited there. It is certain, that when a hole is bored into the trunk of a maple-tree just above its roots, filled with sugar, and then closed again, the sugar is dissolved by the ascending sap. It is further possible that this sugar may be disposed of in the same manner as that formed in the trunks; at all events, it is certain that the introduction of it does not

prevent the action of the juice upon the starch, and since the quantity of the sugar present is now greater than can be exhausted by the leaves and buds, it is excreted from the surface of the leaves or bark.   Certain diseases of trees, for example that called honey-dew, evidently depend on the want of the due proportion between the quantity of the azotised and that of the unazotised substances which are applied to them as nutriment.

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 must be said of humic acid, which is so closely allied to them in composition.

If now we direct our attention to the particular organs of a plant, we find every fibre and every particle of wood surrounded by a juice containing an azotised matter; while the starch, granules, and sugar, are enclosed in cells formed of a substance containing nitrogen.   Indeed, everywhere, in all the juices of the fruits and blossoms, we find a substance destitute of nitrogen, accompanied by one which contains that element.

The wood of the stem cannot be formed *quasi* wood, in the leaves, but another substance must be produced which is capable of being transformed into wood.   This substance must be in a state of solution, and accompanied by a compound containing nitrogen; it is very probable that the wood and the vegetable gluten, the starch granules and the cells containing them, are formed simultaneously, and in this case a certain fixed proportion between them would be a condition necessary for their production.

An abnormal production of certain component parts of plants presupposes a power and capability of-assimilation to which the most powerful chemical action cannot be compared. The best idea of it may be formed by considering that it surpasses in power the strongest galvanic battery, with which we are not able to separate the oxygen from carbonic acid. The affinity of chlorine for hydrogen, and its power to decompose water under the influence of light and set at liberty its oxygen, cannot be considered as at all equalling the power and energy with which a leaf separated from a plant decomposes the carbonic acid which it absorbs.

The common opinion, that only the direct solar rays can effect the decomposition of carbonic acid in the leaves of plants, and that reflected or diffused light does not possess this property, is wholly an error, for exactly the same constituents are generated in a number of plants, whether the direct rays of the sun fall upon them, or whether they grow in the shade. They require light, and indeed sun-light, but it is not necessary that the direct rays of the sun reach them. Their functions certainly proceed with greater intensity and rapidity in sunshine than in the diffused light of day; but there is nothing more in this than the similar action which light exercises on ordinary chemical combinations : it merely accelerates in a greater or less degree the action already subsisting.

Thus chlorine and hydrogen combining form muriatic acid. This combination is effected in a few hours in common daylight, but it ensues instantly, with a violent explosion, under exposure to the direct solar rays, whilst not the slightest change in the two gases takes place in perfect

bones and muscles, become fat, and acquire much *embonpoint;* their limbs appear full, but they do not acquire strength, nor are their organs properly developed.

darkness.   When the liquid hydrocarburet of chlorine, resulting from the union of the olefiant gas of the associated Dutch chemists with chlorine, is exposed in a vessel with chlorine gas to the direct solar rays, chloride of carbon is immediately produced; but the same compound can be obtained with equal facility in the diffused light of day, a longer time only being required.   When this experiment is performed in the way first mentioned, two products only are observed (muriatic acid and perchloride of carbon); whilst by the latter method a class of intermediate bodies are produced, in which the quantity of chlorine constantly augments, until at last the whole liquid hydrocarburet of chlorine is converted into the same two products as in the first case.   Here, also, not the slightest trace of decomposition takes place in the dark.   Nitric acid is decomposed in common daylight into oxygen, and peroxide of nitrogen; and chloride of silver becomes black in the diffused light of day, as well as in the direct solar rays;—in short, all actions of a similar kind proceed in the same way in diffused light as well as in the solar light, the only difference consisting in the time in which they are effected.   It cannot be otherwise in plants, for the mode of their nutriment is the same in all, and their component substances afford proof that their food has suffered absolutely the same change, whether they grow in the sunshine or in the shade.

All the carbonic acid, therefore, which we supply to a plant will undergo a transformation, provided its quantity be not greater than can be decomposed by the leaves. We know that an excess of carbonic acid kills plants, but we know also that nitrogen to a certain degree is not essential for the decomposition of carbonic acid.   All the experiments hitherto instituted prove, that fresh leaves

placed in water impregnated with carbonic acid, and
exposed to the influence of solar light, emit oxygen gas,
whilst the carbonic acid disappears. Now in these expe-
riments no nitrogen is supplied at the same time with the
carbonic acid; hence no other conclusion can be drawn
from them than that nitrogen is not necessary for the
decomposition of carbonic acid,—for the exercise, there-
fore, of one of the functions of plants. And yet the
presence of a substance containing this element appears
to be indispensable for the assimilation of the products
newly formed by the decomposition of the carbonic acid,
and their consequent adaptation for entering into the
composition of the different organs.

The carbon abstracted from the carbonic acid acquires
in the leaves a new form, in which it is soluble and trans-
ferable to all parts of the plant. In this new form the
carbon aids in constituting several new products; these
are named sugar when they possess a sweet taste, gum
or mucilage when tasteless, and excrementitious matters
when expelled by the roots.

Hence it is evident that the quantity and quality of the
substances generated by the vital processes of a plant will
vary according to the proportion of the different kinds of
food with which it is supplied. The development of
every part of a plant in a free and uncultivated state
depends on the amount and nature of the food afforded
to it by the spot on which it grows. A plant is developed
on the most sterile and unfruitful soil as well as on the
most luxuriant and fertile; the only difference which can
be observed being in its height and size, in the number
of its twigs, branches, leaves, blossoms, and fruit. Whilst
the individual organs of a plant increase on a fertile soil,
they diminish on another where those substances which

are necessary for their formation, are not so bountifully supplied; and the proportion of the constituents which contain nitrogen and of those which do not in plants, varies with the amount of nitrogenous matters in their food.

The development of the stem, leaves, blossoms, and fruit of plants is dependent on certain conditions, the knowledge of which enables us to exercise some influence on their internal constituents as well as on their size. It is the duty of the natural philosopher to discover what these conditions are; for the fundamental principles of agriculture must be based on a knowledge of them. There is no profession which can be compared in importance with that of agriculture, for to it belongs the production of food for man and animals ; on it depends the welfare and development of the whole human species, the riches of states, and all commerce. There is no other profession in which the application of correct principles is productive of more beneficial effects, or is of greater and more decided influence. Hence it appears quite unaccountable, that we may vainly search for one leading principle in the writings of agriculturists and vegetable physiologists.

The methods employed in the cultivation of land are different in every country, and in every district; and when we inquire the causes of these differences, we receive the answer, that they depend upon circumstances. (*Les circonstances font les assolements.*) No answer could show ignorance more plainly, since no one has ever yet devoted himself to ascertain what these circumstances are. Thus also when we inquire in what manner manure acts, we are answered by the most intelligent men, that its action is covered by the veil of Isis ; and when we demand fur-

ther what this means, we discover merely that the excre-
ments of men and animals are supposed to contain an in-
comprehensible *something* which assists in the nutrition
of plants, and increases their size.   This opinion is
embraced without even an attempt being made to discover
h e component parts of manure, or to become acquainted
with its nature.

In addition to the general conditions, such as heat,
light, moisture, and the component parts of the atmo-
sphere, which are necessary for the growth of all plants,
certain substances are found to exercise a peculiar influ-
ence on the development of particular families.   These
substances either are already contained in the soil, or are
supplied to it in the form of the matters known under the
general name of manure.   But what does the soil contain,
and what are the components of the substances used as
manure ?   Until these points are satisfactorily determined,
a rational system of agriculture cannot exist.   The power
and knowledge of the physiologist, of the agriculturist and
chemist, must be united for the complete solution of these
questions ; and in order to attain this end, a commence-
ment must be made.

The *general* object of agriculture is to produce in the
most advantageous manner certain qualities, or a maximum
size, in certain parts or organs of particular plants.   Now,
this object can be attained only by the application of those
substances which we know to be indispensable to the
development of these parts or organs, or by supplying the
conditions necessary to the production of the qualities
desired.

The rules of a rational system of agriculture should
enable us, therefore, to give to each plant that which it
* requires for the attainment of the object in view.

The *special* object of agriculture is to obtain an abnormal development and production of certain parts of plants, or of certain vegetable matters, which are employed as food for man and animals, or for the purpose of industry.

The means employed for effecting these two purposes are very different. Thus the mode of culture employed for the purpose of procuring fine pliable straw for Florentine hats, is the very opposite to that which must be adopted in order to produce a maximum of corn from the same plant. Peculiar methods must be used for the production of nitrogen in the seeds, others for giving strength and solidity to the straw, and others again must be followed when we wish to give such strength and solidity to the straw as will enable it to bear the weight of the ears.

We must proceed in the culture of plants in precisely the same manner as we do in the fattening of animals. The flesh of the stag and roe, or of wild animals in general, is quite devoid of fat, like the muscular flesh of the Arab; or it contains only small quantities of it. The production of flesh and fat may be artificially increased; all domestic animals, for example, contain much fat. We give food to animals, which increases the activity of certain organs, and is itself capable of being transformed into fat. We add to the quantity of food, or we lessen the processes of respiration and perspiration by preventing motion. The conditions necessary to effect this purpose in birds are different from those in quadrupeds; and it is well known that charcoal powder produces such an excessive growth of the liver of a goose, as at length causes the death of the animal.

The increase or diminution of the vital activity of vegetables depends only on heat and solar light, which we have not arbitrarily at our disposal; all that we can do is

to supply those substances which are adapted for assimi-
lation by the power already present in the organs of the
plant.   But what then are these substances?   They may
easily be detected by the examination of a soil, which is
always fertile in given cosmical and atmospheric condi-
tions ; for it is evident, that the knowledge of its state and
composition must enable us to discover the circumstances
under which a sterile soil may be rendered fertile.   It is
the duty of the chemist to explain the composition of a
fertile soil, but the discovery of its proper state or condi-
tion belongs to the agriculturist; our present business lies
only with the former.

Arable land is originally formed by the crumbling of
rocks, and its properties depend on the nature of their
principal component parts.   Sand, clay, and lime, are the
names given to the principal constituents of the different
kinds of soil.

Pure sand and pure limestones, in which there are no
other inorganic substances except siliceous earth, car-
bonate or silicate of lime, form absolutely barren soils.
But argillaceous earths form always a part of fertile soils.
Now from whence come the argillaceous earths in arable
land, what are their constituents, and what part do they '
play in favouring vegetation ?   They are produced by the
disintegration of aluminous minerals by the action of the
weather ; the common potash and soda felspars, Labrador
spar, mica, and the zeolites, are the most common alumi-
nous earths, which undergo this change.   These minerals
are found mixed with other substances in granite, gneiss,
mica-slate, porphyry, clay-slate, grauwacke, and the volcanic
rocks, basalt, clinkstone, and lava.   In the grauwacke, we
have pure quartz, clay-slate, and lime ; in the sand-
stones, quartz and loam.   The transition limestone and

the dolomites contain an intermixture of clay, felspar, porphyry, and clay-slate; and the mountain limestone is remarkable for the quantity of argillaceous earths which it contains. Jura limestone contains 3—20, that of the Wurtemberg Alps 45—50 per cent. of these earths. And in the *muschelkalk* and the *calcaire grossier* they exist in greater or less quantity.

It is known, that the aluminous minerals are the most widely diffused on the surface of the earth, and, as we have already mentioned, all fertile soils, or soils capable of culture, contain alumina as an invariable constituent. There must, therefore, be something in aluminous earth which enables it to exercise an influence on the life of plants, and to assist in their development. The property on which this depends is that of its invariably containing potash and soda.

Alumina exercises only an indirect influence on vegetation, by its power of attracting and retaining water and ammonia; it is itself very rarely found in the ashes of plants*, but silica is always present, having in most places entered the plants by means of alkalies. In order to form a distinct conception of the quantities of alkalies in aluminous minerals, it must be remembered that felspar contains 17¾ per cent. of potash, albite 11·48 per cent. of soda, and mica 3—5 per cent.; and that zeolite contains 13—16 per cent. of both alkalies taken together. The late analyses of Ch. Gmelin, Lowe, Fricke, Meyer, and Redtenbacher, have also shown, that basalt contains from ¾ to 3 per cent. of potash, and from 5—7 per cent. of soda;

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* Alumina is generally supposed to be a common ingredient of the ashes of plants, and it is very frequently stated in the results of their analyses; but in most cases it has been mistaken for phosphate of magnesia, or phosphate of alumina, with which it has many properties in common, and from which it cannot be distinguished without much care and attention.—ED.

that clay-slate contains from 2·75—3·31 per cent of potash, and loam from 1½—4 per cent. of potash.

If, now, we calculate from these data, and from the specific weights of the different substances, how much potash must be contained in a layer of soil, which has been formed by the disintegration of 26,910 square feet (1 Hessian acre) of one of these rocks to the depth of 20 inches, we find that a soil of

Felspar	contains	. . . . .	1,675,000 lbs.
Clinkstone	,,	from 220,000 to 440,000	,,
Basalt	,,	,, 52,300 ,, 82,600	,,
Clay-slate	,,	,, 110,000 ,, 220,000	,,
Loam	,,	,, 95,000 ,, 330,000	,,

Potash is present in all clays; according to Fuchs, it is contained even in marl; it has been found in all the argillaceous earths in which it has been sought. The fact that they contain potash may be proved in the clays of the transition and stratified mountains, as well as in the recent formations surrounding Berlin, by simply digesting them with sulphuric acid, by which process alum is formed. (Mitscherlich.) It is well known also to all manufacturers of alum, that the leys contain a certain quantity of this salt ready formed, the potash of which has its origin from the ashes of the stone and brown coal, which contain much argillaceous earth.

When we consider this extraordinary distribution of potash over the surface of the earth, is it reasonable to have recourse to the idea, that the presence of this alkali in plants is due to the generation of a metallic oxide by a peculiar organic process from the component parts of the atmosphere? This opinion found adherents even after the method of detecting potash in soils was known, and suppositions of the same kind may be found even in the

writings of some physiologists of the present day. Such opinions belong properly to the time when flint was conceived to be a product of chalk, and when everything which appeared incomprehensible on account of not having been investigated, was explained by assumptions far more incomprehensible.

A thousandth part of loam mixed with the quartz in new red sandstone, or with the lime in the different limestone formations, affords as much potash to a soil only twenty inches in depth as is sufficient to supply a forest of pines growing upon it for a century. A single cubic foot of felspar is sufficient to supply a wood, covering a surface of 26,910 square feet, with the potash required for five years.

Land of the greatest fertility contains argillaceous earths and other disintegrated minerals, with chalk and sand in such a proportion as to give free access to air and moisture. The land in the vicinity of Vesuvius may be considered as the type of a fertile soil, and its fertility is greater or less in different parts, according to the proportion of clay or sand which it contains.

The soil which is formed by the disintegration of lava cannot possibly, on account of its origin, contain the smallest trace of vegetable matter; and yet it is well known that when the volcanic ashes have been exposed for some time to the influence of air and moisture, a soil is gradually formed in which all kinds of plants grow with the greatest luxuriance. This fertility is owing to the alkalies which are contained in the lava, and which by exposure to the weather are rendered capable of being absorbed by plants. Thousands of years have been necessary to convert stones and rocks into the soil of arable land, and thousands of years more will be requi-

site for their perfect reduction, that is, for the complete
exhaustion of their alkalies.   •

We see from the composition of the water in rivers,
streamlets, and springs, how little rain-water is able to
extract alkali from a soil, even after a term of years ; this
water is generally soft, and the common salt, which even
the softest invariably contains, proves that those alkaline
salts, which are carried to the sea by rivers and streams,
are returned again to the land by wind and rain.

Nature itself shows us what plants require at the com-
mencement of the development of their germs and first
radicle fibres. Bequerel has shown that the *graminea,*
leguminosæ, cruciferæ, cichoraceæ, umbelliferæ, coniferæ,
and *cucurbitaceæ* emit acetic acid during germination.
A plant which has just broken through the soil, and a
leaf just burst open from the bud, furnish acids by inci-
neration, which contain as much, and generally more, of
alkaline salts than at any period of their life. (De Saus-
sure.) Now we know also, from the experiments of
Bequerel, in what manner these alkaline salts enter young
plants ; the acetic acid formed during germination is dif-
fused through the wet or moist soil, becomes saturated
with lime, magnesia, and alkalies, and is again absorbed
by the radicle fibres in the form of neutral salts. After
the cessation of life, when plants are subjected to decom-
position by means of decay and putrefaction, the soil
receives again that which had been extracted from it.

Let us suppose that a soil has been formed by the
action of the weather on the component parts of granite,
grauwacke, mountain limestone, or porphyry, and that
nothing has vegetated on it for thousands of years. Now
this soil would become a magazine of alkalies in a con-
dition favourable for their assimilation by the roots of
plants.

The interesting experiments of Struve have proved that water impregnated with carbonic acid decomposes rocks which contain alkalies, and then dissolves a part of the alkaline carbonates. It is evident that plants also, by producing carbonic acid during their decay, and by means of the acids which exude from their roots in the living state, contribute no less powerfully to destroy the coherence of rocks. Next to the action of air, water, and change of temperature, plants themselves are the most powerful agents in effecting the disintegration of rocks.

Air, water, and the change of temperature prepare the different species of rocks for yielding to plants the alkalies which they contain. A soil which has been exposed for centuries to all the influences which affect the disintegration of röcks, but from which the alkalies have not been removed, will be able to afford the means of nourishment to those vegetables which require alkalies for its growth during many years; but it must gradually become exhausted, unless those alkalies which have been removed are again replaced : a period, therefore, will arrive when it will be necessary to expose it from time to time to a further disintegration, in order to obtain a new supply of soluble alkalies. For small as is the quantity of alkali which plants require, it is nevertheless quite indispensable for their perfect development. But when one or more years have elapsed without any alkalies having been extracted from the soil, a new harvest may be expected.

The first colonists of Virginia found a country the soil of which was similar to that mentioned above; harvests of wheat and tobacco were obtained for a century from one and the same field, without the aid of manure; but now whole districts are converted into unfruitful pasture-land, which without manure produces neither wheat nor

tobacco.   From every acre of this land there were re-
moved in the space of one hundred years 12,000 lbs. of
alkalies in leaves, grain, and straw ; it became unfruitful,
therefore, because it was deprived of every particle of
alkali, which had been reduced to a soluble state, and
because that which was rendered soluble again in the
space of one year was not sufficient to satisfy the demands
of the plants.   Almost all the cultivated land in Europe
is in this condition ; fallow is the term applied to land
left at rest for further disintegration.   It is the greatest
possible mistake to suppose that the temporary diminu-
tion of fertility in a soil is owing to the loss of humus;
it is the mere consequence of the exhaustion of the
alkalies.

Let us consider the condition of the country around
Naples, which is famed for its fruitful corn-land : the
farms and villages are situated from eighteen to twenty-
four miles distant from one another, and between them
there are no roads, and consequently no transportation
of manure.   Now corn has been cultivated on this land
for thousands of years, without any part of that which is
annually removed from the soil being artificially restored
to it.   How can any influence be ascribed to humus
under such circumstances, when it is not even known
whether humus was ever contained in the soil ?

The method of culture in that district completely
explains the permanent fertility.   It appears very bad in
the eyes of our agriculturists, but there it is the best plan
which could be adopted.   A field is cultivated once every
three years, and is in the intervals allowed to serve as a
sparing pasture for cattle.   The soil experiences no
change in the two years during which it there lies fallow,
further than that it is exposed to the influence of the

weather, by which a fresh portion of the alkalies contained in it are again set free or rendered soluble. The animals fed on these fields yield nothing to these soils which they did not formerly possess. The weeds upon which they live spring from the soil, and that which they return to it as excrement must always be less than that which they extract. The fields, therefore, can have gained nothing from the mere feeding of cattle upon them; on the contrary, the soil must have lost some of its constituents.

Experience has shown in agriculture that wheat should not be cultivated after wheat on the same soil, for it belongs with tobacco to the plants which exhaust a soil. But if the humus of a soil gives it the power of producing corn, how happens it that wheat does not thrive in many parts of Brazil, where the soils are particularly rich in this substance, or in our own climate, in soils formed of moulded wood; that its stalk under these circumstances attains no strength, and droops prematurely? The cause is this, that the strength of the stalk is due to silicate of potash, and that the corn requires phosphate of magnesia, neither of which substances a soil of humus can afford, since it does not contain them; the plant may, indeed, under such circumstances, become an herb, but will not bear fruit.

Again, how does it happen that wheat does not flourish on a sandy soil, and that a calcareous soil is also unsuitable for its growth, unless it be mixed with a considerable quantity of clay*? It is because these soils do

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* In consequence of these remarks in the former edition of this work, Professor Wöhler of Gottingen has made several accurate analyses of different kinds of limestone belonging to the secondary and tertiary formations. He obtained the remarkable result, that all those limestones, by the disintegration of which soils adapted for the culture of wheat are

not contain alkalies in sufficient quantity, the growth of
wheat being arrested by this circumstance, even should
all other substances be presented in abundance.

It is not mere accident that only trees of the fir tribe
grow on the sandstone and limestone of the Carpathian
mountains and the Jura, whilst we find on soils of gneiss,
mica-slate, and granite in Bavaria, of clinkstone on the
Rhone, of basalt in Vogelsberge, and of clay-slate on the
Rhine and Eifel, the finest forests of other trees, which
cannot be produced on the sandy or calcareous soils upon
which pines thrive. It is explained by the fact that trees,
the leaves of which are renewed annually, require for their
leaves six to ten times more alkalies than the fir-tree or
pine, and hence when they are placed in soils in which
alkalies are contained in very small quantity, do not
attain maturity*. When we see such trees growing on
a sandy or calcareous soil—the red-beech, the service-
tree, and the wild-cherry for example, thriving luxuriantly
on limestone, we may be assured that alkalies are present
in the soil, for they are necessary to their existence.
Can we, then, regard it as remarkable that such trees
should thrive in America, on those spots on which forests
of pines which have grown and collected alkalies for centu-
ries, have been burnt, and to which the alkalies are thus at
once restored; or that the *Spartium scoparium*, *Erysi-
mum latifolium*, *Blitum capitatum*, *Senecio viscosus*, plants
remarkable for the quantity of alkalies contained in their

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formed, invariably contain a certain quantity of potash. The same ob-
servation has also recently been made by M. Kuhlmann of Lille. The
latter observed that the efflorescence on the mortar of walls consists of
the carbonates of soda and potash.

* One thousand parts of the dry leaves of oaks yielded 55 parts of
ashes, of which 24 parts consisted of alkalies soluble in water; the same
quantity of pine-leaves gave only 29 parts of ashes, which contain 4·6
parts of soluble salts. (De Saussure.)

ashes, should grow with the greatest luxuriance on the localities of conflagrations *?

Wheat will not grow on a soil which has produced wormwood, and, *vice versâ*, wormwood does not thrive where wheat has grown, because they are mutually prejudicial by appropriating the alkalies of the soil.

One hundred parts of the stalks of wheat yield 15·5 parts of ashes (H. Davy); the same quantity of the dry stalks of barley, 8·54 parts (Schrader); and one hundred parts of the stalks of oats, only 4·42 ;—the ashes of all these are of the same composition.

We have in these facts a clear proof of what plants require for their growth. Upon the same field, which will yield only one harvest of wheat, two crops of barley and three of oats may be raised.

All plants of the grass kind require silicate of potash. Now this is conveyed to the soil, or rendered soluble in it, by the irrigation of meadows. The *equisetaceæ*, the reeds and species of cane, for example, which contain such large quantities of siliceous earth, or silicate of potash, thrive luxuriantly in marshes, in argillaceous soils, and in ditches, streamlets, and other places where the change of water renews constantly the supply of dissolved silica. The amount of silicate of potash removed from a meadow in the form of hay is very considerable. We need only call to mind the melted vitreous mass found on a meadow between Manheim and Heidelberg after a thunder-storm. This mass was at first supposed to be

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* After the great fire in London, large quantities of the *Erysimum latifolium* were observed growing on the spots where a fire had taken place. On a similar occasion the *Blitum capitatum* was seen at Copenhagen, the *Senecio viscosus* in Nassau, and the *Spartium scoparium* in Languedoc. After the burnings of forests of pines in North America, poplars grew on the same soil.

cultivated*. These other matters, we must suppose, supply, in part at least, the place and perform the functions of the substances just named. We may thus regard common salt, sulphate of potash, nitre, chloride of potassium, and other matters, as necessary constituents of several plants.

Clay-slate contains generally small quantities of oxide of copper; and soils formed from micaceous schist contain some metallic fluorides. Now, small quantities of these substances also are absorbed into plants, although we cannot affirm that they are necessary to them.

It appears that in certain cases fluoride of calcium may take the place of the phosphate of lime in the bones and teeth; at least it is impossible otherwise to explain its constant presence in the bones of antediluvian animals, by which they are distinguished from those of a later period. The bones of human skulls found at Pompeii contain as much fluoric acid as those of animals of a former world, for if they be placed in a state of powder in glass vessels, and digested with sulphuric acid, the interior of the vessel will, after twenty-four hours, be found powerfully corroded (Liebig); whilst the bones and teeth of animals of the present·day contain only traces of it. (Berzelius.)

De Saussure remarked that plants require unequal quantities of the component parts of soils in different stages of their development; an observation of much importance in considering the growth of plants. Thus, wheat yielded $\frac{72}{1000}$ of ashes a month before blossoming, $\frac{14}{1000}$ while in blossom, and $\frac{33}{1000}$ after the ripening of the seeds. It is therefore evident that wheat, from the

* For more minute information regarding soils see the supplementary Chapter at the end of Part I.

time of its flowering, restores a part of its organic con-
stituents to·the soil, although the phosphate of magnesia
remains in the seeds.

The fallow-time, as we have already shown, is that
period of culture during which land is exposed to a pro-
gressive disintegration by means of the influence of the
atmosphere, for the purpose of rendering a certain quan-
tity of alkalies capable of being appropriated by plants.

Now, it is evident, that the careful tilling of fallow-land
must increase and accelerate this disintegration. For the
purpose of agriculture, it is quite indifferent, whether the
land is covered with weeds, or with a plant which does
not abstract the potash inclosed in it. Now many plants
in the family of the *leguminosæ* are remarkable on account
of the small quantity of alkalies or salts in general which
they contain ; the Windsor bean (*Vicia Faba*), for exam-
ple, contains no free alkalies, and not one per cent. of the
phosphates of lime and magnesia. (Einhof.) The bean of
the kidney-bean (*Phaseolus vulgaris*) contains only traces
of salts. (Braconnot.) The stem of Lucern (*Medicago
sativa*) contains only 0·83 per cent., that of the Lentil
(*Ervum Lens*) only 0·57 of phosphate of lime with
albumen. (Crome.) Buck-wheat dried in the sun yields
only 0·681 per cent. of ashes, of which 0·09 parts are
soluble salts. (Zenneck.)* These plants belong to those

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* The small quantity of phosphates which the seeds of the lentils,
beans, and peas contain, must be the cause of their small value as articles
of nourishment, since they surpass all other vegetable food in the quantity
of nitrogen which enters into their composition. But as the component
parts of the bones (phosphate of lime and magnesia) are absent, they
satisfy the appetite without increasing the strength. The following
is an analysis of lentils (Playfair). 6·092 grammes lost 0·972 grammes of
water at 212°. 0·566 grammes, burned with oxide of copper, gave 0·910
grammes carbonic acid and 0·336 grammes of water. The lentils, on com-

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which are termed fallow-crops, and the cause wherefore
they do not exercise any injurious influence on corn which
is cultivated immediately after them is, that they do not
extract the alkalies of the soil, and only a very small
quantity of phosphates.

It is evident that two plants growing beside each other
will mutually injure one another, if they withdraw the
same food from the soil.   Hence it is not surprising that
the wild chamomile (*Matricaria Chamomilla*) and Scotch
broom (*Spartium Scoparium*) impede the growth of corn,
when it is considered that both yield from 7 to 7·43 per
cent. of ashes, which contain $\frac{6}{10}$ of carbonate of potash.
The darnel and the fleabane (*Erigeron acre*) blossom
and bear fruit at the same time as corn, so that when
growing mingled with it, they will partake of the compo-
nent parts of the soil, and in proportion to the vigour of
their growth, that of the corn must decrease; for what
one receives, the others are deprived of.   Plants will, on
the contrary, thrive beside each other, either when the
substances necessary for their growth which they extract
from the soil are of different kinds, or when they them-
selves are not both in the same stages of development at
the same time.

On a soil, for example, which contains potash, both
wheat and tobacco may be reared in succession, because
the latter plant does not require phosphates, salts which
are invariably present in wheat, but requires only alkalies,
and food containing nitrogen.

bustion with oxide of copper, yielded a gas, in which the proportion of
the nitrogen to the carbonic acid was as 1 : 16.

Carbon	44·45
Hydrogen	6·59
Nitrogen	6·42
Water	15·95

According to the analysis of Posselt and Reimann, 10,000 parts of the leaves of the tobacco-plant contain 16 parts of phosphate of lime, 8·8 parts of silica, and no magnesia; whilst an equal quantity of wheat-straw contains 47·3 parts, and the same quantity of the grain of wheat 99·45 parts of phosphates. (De Saussure.)

Now, if we suppose that the grain of wheat is equal to half the weight of its straw, then the quantity of phosphates extracted from a soil by the same weights of wheat and tobacco must be as 97·7:16. This difference is very considerable. The roots of tobacco, as well as those of wheat, extract the phosphates contained in the soil, but they restore them again, because they are not essentially necessary to the development of the plant.

CHAPTER VIII.

ON THE ALTERNATION OF CROPS.

It has long since been found by experience, that the growth of annual plants is rendered imperfect, and their crops of fruit or herbs less abundant, by cultivating them in successive years on the same soil, and that, in spite of the loss of time, a greater quantity of grain is obtained when a field is allowed to lie uncultivated for a year. During this interval of rest, the soil, in a great measure, regains its original fertility.

It has been further observed, that certain plants, such as peas, clover, and flax, thrive on the same soil only after a lapse of years; whilst others, such as hemp, tobacco, *Helianthus tuberosus*, rye, and oats, may be cultivated in close succession when proper manure is used. It has also been found, that several of these plants improve the soil, whilst others, and these are the most numerous, impoverish or exhaust it. Fallow turnips, cabbage, beet, spelt, summer and winter barley, rye and oats, are considered to belong to the class which impoverish a soil; whilst by wheat, hops, madder, late turnips, hemp, poppies, teasel, flax, weld, and licorice, it is supposed to be entirely exhausted.

The excrements of man and animals have been employed from the earliest times for the purpose of increasing the fertility of soils; and it is completely established by all

experience, that they restore certain constituents to the soil, which are removed with the roots, fruit, or grain, or entire plants grown upon it.

But it has been observed that the crops are not always abundant in proportion to the quantity of manure employed, even although it may have been of the most powerful kind; that the produce of many plants, for example, diminishes, in spite of the apparent replacement by manure of the substances removed from the soil, when they are cultivated on the same field for several years in succession.

On the other hand, it has been remarked, that a field which has become unfitted for a certain kind of plants was not on that account unsuited for another; and upon this observation, a system of agriculture has been gradually founded, the principal object of which is to obtain the greatest possible produce with the least expense of manure.

Now it was deduced from all the foregoing facts, that plants require for their growth different constituents of soil; and it was very soon perceived, that an alternation of the plants cultivated maintained the fertility of a soil quite as well as leaving it at rest or fallow. It was evident that all plants must give back to the soil in which they grow different proportions of certain substances, which are capable of being used as food by a succeeding generation.

But agriculture has hitherto never sought aid from chemical principles, based on the knowledge of those substances which plants extract from the soil on which they grow, and of those restored to the soil by means of manure. The discovery of such principles will be the task of a future generation, for what can be expected from the present, which recoils with seeming distrust and aversion

from all the means of assistance offered it by chemistry,
and which does not understand the art of making a rational
application of chemical discoveries? A future generation,
however, will derive incalculable advantage from these
means of help.

Of all the views which have been adopted regarding
the cause of the favourable effects of the alternations of
crops, that proposed by M. Decandolle alone deserves to
be mentioned as resting on a firm basis.

Decandolle supposes that the roots of plants imbibe
soluble matter of every kind from the soil, and thus
necessarily absorb a number of substances which are not
adapted to the purposes of nutrition, and must subse-
quently be expelled by the roots, and returned to the soil
as excrements. Now as excrements cannot be assimilated
by the plant which ejected them, the more of these
matters which the soil contains, the more unfertile must
it be for the plants of the same species. These excremen-
titious matters may, however, still be capable of assimila-
tion by another kind of plants, which would thus remove
them from the soil, and render it again fertile for the first.
And if the plants last grown also expel substances from
their roots, which can be appropriated as food by the
former, they will improve the soil in two ways.

Now a great number of facts appear at first sight to
give a high degree of probability to this view. Every
gardener knows that a fruit-tree cannot be made to grow
on the same spot where another of the same species has
stood; at least not until after a lapse of several years.
Before new vine-stocks are planted in a vineyard from
which the old have been rooted out, other plants are cul-
tivated on the soil for several years. In connexion with
this it has been observed, that several plants thrive best

when growing beside one another; and, on the contrary,
that others mutually prevent each other's development.
Whence it was concluded, that the beneficial influence in
the former case depended on a mutual interchange of
nutriment between the plants, and the injurious one in the
latter on a poisonous action of the excrements of each on
the other respectively.

A series of experiments by Macaire-Princep gave great
weight to this theory. He proved beyond all doubt that
many plants are capable of emitting extractive matter
from their roots. He found that the excretions were
greater during the night than by day (?), and that the
water in which plants of the family of the *Leguminosæ*
grew acquired a brown colour. Plants of the same
species placed in water impregnated with these excre-
ments were impeded in their growth, and faded prema-
turely, whilst, on the contrary, corn-plants grew vigorously
in it, and the colour of the water diminished sensibly;
so that it appeared as if a certain quantity of the excre-
ments of the *Leguminosæ* had really been absorbed by
the corn-plants. These experiments afforded, as their
main result, that the characters and properties of the
excrements of different species of plants are different
from one another, and that some plants expel excremen-
titious matter of an acrid and resinous character; others,
mild substances resembling gum. The former of these,
according to Macaire-Princep, may be regarded as poi-
sonous, the latter as nutritious.

The experiments of Macaire-Princep afford positive
proof that the roots, probably, of all plants, expel matters
which cannot be converted in their organism either into
woody fibre, starch, vegetable albumen, or gluten, since
their expulsion indicates that they are quite unfitted for

this purpose. But they cannot be considered as a confirmation of the theory of Decandolle, for they leave it quite undecided whether the substances were extracted from the soil, or formed by the plant itself from food received from another source. It is certain that the gummy and resinous excrements observed by Macaire-Princep could not have been contained in the soil, and as we know that the carbon of a soil is not diminished by culture, but, on the contrary, increased, we must conclude that all excrements which contain carbon must be formed from the food obtained by plants from the atmosphere. Now, these excrements are compounds, produced in consequence of the transformations of the food, and of the new forms which it assumes by entering into the composition of the various organs.

M. Decandolle's theory is properly a modification of an earlier hypothesis, which supposed that the roots of different plants extracted different nutritive substances from the soil, each plant selecting that which was exactly suited for its assimilation. According to this hypothesis, the matters incapable of assimilation are not extracted from the soil, whilst M. Decandolle considers that *they are returned* to it in the form of excrements. Both views explain how it happens that after corn, corn cannot be raised with advantage, nor after peas, peas; but they do not explain how a field is improved by lying fallow, and this in proportion to the care with which it is tilled and kept free from weeds; nor do they show how a soil gains carbonaceous matter by the cultivation of certain plants, such as lucern and sainfoin.

Theoretical considerations on the process of nutrition, as well as the experience of all agriculturists, so beautifully illustrated by the experiments of Macaire-Princep,

leave no doubt that substances are excreted from the roots
of plants, and that these matters form the means by which
the carbon received from humus in the early period of
their growth is restored to the soil. But we may now
inquire whether these excrements, in the state in which
they are expelled, are capable of being employed as food
by other plants.

The excrements of a carnivorous animal contain no con-
stituents fitted for the nourishment of another of the same
species; but it is possible that an herbivorous animal, a
fish, or a fowl, might find in them undigested matters
capable of being digested in their organism, from the
very circumstance of their organs of digestion having a
different structure. This is the only sense in which we
can conceive that the excrements of one animal could yield
matter adapted for the nutrition of another.

A number of substances contained in the food of
animals pass through their alimentary organs without
change, and are expelled from the system; these are
excrements, but not excretions. Now a part of such
excrementitious matter might be assimilated in passing
through the digestive apparatus of another animal. The
organs of secretion form combinations of which only the
elements were contained in the food. The production
of these new compounds is a consequence of the changes
which the food undergoes in becoming chyle and chyme,
and of the further transformations to which these are
subjected by entering into the composition of the organ-
ism. These matters, likewise, are eliminated in the
excrements, which must therefore consist of two dif-
ferent kinds of substances, namely, of the indigestible
constituents of the food, and of the new compounds
formed by the vital process. The latter substances have

the destruction or conversion into humus of the excrements contained in it, which is effected during the fallow season, at the same time that the land is exposed to a further disintegration.

In the soils in the neighbourhood of the Rhine and Nile, which contain much potash, and where crops can be obtained in close succession from the same field, the fallowing of the land is superseded by the inundation; the irrigation of meadows effects the same purpose. It is 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 cultivation of meadows forms one of the most important branches of rural economy. It contributes materially to the prosperity of the agriculturist by increasing his stock of cattle, and consequently by furnishing him with manure, which may be applied to the augmentation of his crops. Indeed, the great progress which has been made in Germany in the improvement of cattle is mainly attributable to the attention which is devoted in that country to the culture of meadows. The environs of Siegin, in Nassau, are particularly famed in this respect,

and every year a large number of young farmers repair
to it, for the purpose of studying this branch of agricul-
ture *in situ.* In that district the culture of grass has
attained such great perfection, that the produce of their
meadow-land far exceeds that obtained in any other part
of Germany. This is effected simply by preparing the
ground in such a manner as to enable it to be irrigated
both in spring and in autumn. The surface of the soil
is fitted to suit the locality, and the quantity of water
which can be commanded. Thus if the meadows be
situated upon a declivity, banks of from one to two feet
in height are raised at short distances from each other.
The water is admitted by small channels upon the most
elevated bank, and allowed to discharge itself over the
sides in such a manner as to run upon the bank situated
below. The grass grown upon meadows irrigated in
this way is three or four times higher than that obtained
from fields which are covered with water that is deprived
of all egress and renewal.

It follows from what has preceded, that the advantage
of the alternation of crops is owing to two causes.

A fertile soil ought to afford to a plant all the inorganic
bodies indispensable for its existence in sufficient quantity
and in such condition as allows their absorption.

All plants require alkalies, which are contained in some,
in the *Gramineæ* for example, in the form of silicates ; in
others, in that of tartrates, citrates, acetates, or oxalates.

When these alkalies are in combination with silicic
acid, the ashes obtained by the incineration of the plant
contain no carbonic acid ; but when they are united with
organic acids, the addition of a mineral acid to their ashes
causes an effervescence.

A third species of plants requires phosphate of lime,

another phosphate of magnesia, and several do not thrive
without carbonate of lime.

Silicic acid is the first solid substance taken up by
plants ; it appears to be the material from which the for-
mation of the wood takes its origin, acting like a grain of
sand around which the first 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.

When we grow in the same soil for several years in
succession different plants, the first of which leaves
behind that which the second, and the second that which
the third may require, the soil will be a fruitful one for all
the three kinds of produce. If the first plant, for example,
be wheat, which consumes the greatest part of the silicate
of potash in a soil, whilst the plants which succeed it are
of such a kind as require only small quantities of potash,
as is the case with *Leguminosæ*, turnips, potatoes, &c.,
the wheat may be again sowed with advantage after the
fourth year ; for during the interval of three years the
soil will, by the action of the atmosphere, be rendered
capable of again yielding silicate of potash in sufficient
quantity for the young plants.

The same precautions must be observed with regard
to the other inorganic constituents, when it is desired to
grow different plants in succession on the same soil: for
a successive growth of plants which extract the same
component parts, must gradually render it incapable of
producing them.   Each of these plants during its growth

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* Silica is found in the joints of bamboos, in the form of small round
globules, which have received the name of *Tabasheer*, and are distin-
guished by their remarkable antical-properties.

returns to the soil a certain quantity of substances containing carbon, which are gradually converted into humus, and are for the most part equivalent to as much carbon as the plants had formerly extracted from the soil in a state of carbonic acid.   But although this is sufficient to bring many plants to maturity, it is not enough to furnish their different organs with the greatest possible supply of nourishment.   Now the object of agriculture is to produce either articles of commerce, or food for man and animals ; but a maximum of produce in plants is always in proportion to the quantity of nutriment supplied to them in the first stage of their development.

The nutriment of young plants consists of carbonic acid, contained in the soil in the form of humus, and of nitrogen in the form of ammonia, both of which must be supplied to the plants, if the desired purpose is to be accomplished.   The formation of ammonia cannot be effected on cultivated land, but humus may be artificially produced; and this must be considered as an important object in the alternation of crops, and as the second reason of its peculiar advantages.

The sowing of a field with fallow plants, such as clover, rye, buck-wheat, &c., and the incorporation of the plants, when nearly at blossom, with the soil, affect this supply of humus in so far, that young plants subsequently growing in it find, at a certain period of their growth, a maximum of nutriment, that is, matter in the process of decay.

The same end is obtained, but with much greater certainty, when the field is planted with sainfoin or lucerne*.

* The alternation of crops with sainfoin and lucerne is now universally adopted in Bingen and its vicinity, as well as in the Palatinate ; the fields in these districts receive manure only once every nine years.   In the first

These plants are remarkable on account of the great ramification of their roots, and strong development of their leaves, and for requiring only a small quantity of inorganic matter. Until they reach a certain period of their growth, they retain all the carbonic acid and ammonia which may have been conveyed to them by rain and the air, for that which is not absorbed by the soil is appropriated by the leaves; they also possess an extensive four or six-fold surface, capable of assimilating these bodies, and of preventing the volatilization of the ammonia from the soil, by completely covering it in.

An immediate consequence of the production of the green principle of the leaves, and of their remaining component parts, as well as those of the stem, is the equally abundant excretion of organic matters into the soil from the roots.

The favourable influence which this exercises on the land, by furnishing it with matter capable of being converted into humus, lasts for several years, but barren spots gradually appear after the lapse of some time. Now it is evident that, after from six to seven years, the ground must become so impregnated with excrements, that every fibre of the root will be surrounded with them. As they remain for some time in a soluble condition, the plants must absorb part of them and suffer injurious effects in consequence, because they are not capable of assimilation. When such a field is observed for several years, it is seen that the barren spots are again covered with vegetation, (the same plants being always supposed to be grown,) whilst new spots become bare and apparently

years after the land has been manured turnips are sown upon it, in the next following years barley, with sainfoin or lucerne; in the seventh year potatoes, in the eighth wheat, in the ninth barley; on the tenth year it is manured, and then the same rotation again takes place.

unfruitful, and so on alternately. The causes which pro-
duce this alternate barrenness and fertility in the different
parts of the land are evident. The excrements upon the
barren spots receiving no new addition, and being sub-
jected to the influence of air and moisture, they pass
into putrefaction, and their injurious influence ceases.
The plants now find those substances which formerly
prevented their growth removed, and in their place meet
with humus, that is, vegetable matter in the act of decay.

We can scarcely suppose a better means of producing
humus than by the growth of plants, the leaves of which
are food for animals; for they prepare the soil for plants
of every other kind, but particularly for those to which,
as to rape and flax, the presence of humus is the most
essential condition of growth.

The reasons why this interchange of crops is so advan-
tageous—the principles which regulate this part of agri-
culture, are, therefore, the artificial production of humus,
and the cultivation of different kinds of plants upon the
same field, in such an order of succession, that each shall
extract only certain components of the soil, whilst it
leaves behind or restores those which a second or third
species of plant may require for its growth and perfect
development.

Now, although the quantity of humus in a soil may be
increased to a certain degree by an artificial cultivation,
still, in spite of this, there cannot be the smallest doubt
that a soil must gradually lose those of its constituents
which are removed in the seeds, roots, and leaves of the
plants raised upon it. The fertility of a soil cannot
remain unimpaired, unless we replace in it all those sub-
stances of which it has been thus deprived.

Now this is effected by *manure.*

CHAPTER IX.

OF MANURE.

WHEN it is considered that every constituent of the body of man and animals is derived from plants, and that not a single element is generated by the vital principle, it is evident that all the inorganic constituents of the animal organism must be regarded, in some respect or other, as manure. During their life, the inorganic components of plants which are not required by the animal system, are disengaged from the organism, in the form of excrements. *After their death, their nitrogen and carbon pass into the* atmosphere as ammonia and carbonic acid, the products of their putrefaction, and at last nothing remains except the phosphate of lime and other salts in their bones. Now this earthy residue of the putrefaction of animals must be considered, in a rational system of agriculture, as a powerful manure for plants, because that which has been abstracted from a soil for a series of years must be restored to it, if the land is to be kept in a permanent condition of fertility.

ANIMAL MANURES.

We may now inquire whether the excrements of animals, which are employed as manure, are all of a like nature and power, and whether they, in every case, administer to the necessities of a plant by an identical mode of

action. These points may easily be determined by ascertaining the composition of the animal excrements, because we shall thus learn what substances a soil really receives by their means. According to the common view, the action of solid animal excrements depends on the decaying organic matters which replace the humus, and on the presence of certain compounds of nitrogen, which are supposed to be assimilated by plants, and employed in the production of gluten and other azotised substances. But this view requires further confirmation with respect to the solid excrements of animals, for they contain so small a proportion of nitrogen, that they cannot possibly by means of it exercise any influence upon vegetation.

We may form a tolerably correct idea of the chemical nature of the animal excrement without further examination, by comparing the excrements of a dog with its food. When a dog is fed with flesh and bones, both of which consist in great part of organic substances containing nitrogen, a moist white excrement is produced which crumbles gradually to a dry powder in the air. This excrement consists of the phosphate of lime of the bones, and contains scarcely $\frac{1}{160}$ part of its weight of foreign organic substances. The whole process of nutrition in an animal consists in the progressive extraction of all the nitrogen from the food, so that the quantity of this element found in the excrements must always be less than that contained in the nutriment. The analysis of the excrements of a horse by Macaire and Marcet proves this fact completely. The portion of excrements subjected to analysis was collected whilst fresh, and dried *in vacuo* over sulphuric acid; 100 parts of it (corresponding to from 350 to 400 parts of the dung before being dried) contained 0·8 of nitrogen. Now every one who has had experience in

this kind of analysis is aware that a quantity under one
per cent. cannot be determined with accuracy. We
should, therefore, be estimating its proportion at a max-
imum, were we to consider it as equal to one-half per
cent. It is certain, however, that these excrements are
not entirely free from nitrogen, for they emit ammonia
when digested with caustic potash.

The excrements of a cow, on combustion with oxide of
copper, yielded a gas which contained one vol. of nitrogen
gas, and 26·30 vol. of carbonic acid.

100 parts of fresh excrements contained

Nitrogen	.	.	.	0·506
Carbon	.	.	. .	6·204
Hydrogen	.	.	.	0·824
Oxygen	.	.	. .	4·818
Ashes	.	.	.	1·748
Water .	.	.	. .	85·900
				100·000

Now, according to the analysis of Boussingault, which
merits the greatest confidence, hay contains one per cent.
of nitrogen; consequently in the 25 lbs. of hay which a
cow consumes daily, ¼ of a lb. of nitrogen must have been
assimilated. This quantity of nitrogen entering into the
composition of muscular fibre would yield 8·3 lbs. of flesh
in its natural condition *. The daily increase in size of a
cow is, however, much less than this quantity. We find
that the nitrogen, apparently deficient, is actually con-
tained in the milk and urine of the animal. The urine
of a milch-cow contains less nitrogen than that of one
which does not yield milk; and as long as a cow yields
a plentiful supply of milk, it cannot be fattened. We
must search for the nitrogen of the food assimilated, not

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* 100 lbs. of flesh contain on an average 15·86 of muscular fibre: 18
parts of nitrogen are contained in 100 parts of the latter.

in the solid, but in the liquid excrements. The influence which the former exercise on the growth of vegetables does not depend upon the quantity of nitrogen which they contain. For if this were the case, hay should possess the same influence ; that is, from 20 to 25 lbs. ought to have the same power as 100 lbs. of fresh cow-dung. But this is quite opposed to all experience.

Which then are the substances in the excrements of the cow and horse which exert an influence on vegetation?

When horse-dung is treated with water, a portion of it to the amount of 3 or $3\frac{1}{2}$ per cent. is dissolved, and the water is coloured yellow. The solution is found to con-tain phosphate of magnesia, and salts of soda, besides small quantities of organic matters*. The portion of the dung undissolved by the water yield to alcohol a resinous substance, possessing all the characters of gall which has undergone some change ; while the residue possesses the

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* Dr. C. T. Jackson in his " Geological and Agricultural Survey of Rhode Island," (page 205) gives the following analysis of horse-dung :— 500 grains, dried at a heat a little above that of boiling water, lost 357 grains of water. The dry mass weighing 143 grains was burned, and left 8·5 grains of ashes, of which 4·80 grains were soluble in dilute nitric acid, and 3·20 insoluble. The ashes being analysed, gave

Silica	3·2
Phosphate of lime	0·4
Carbonate of lime	1·5
* Phosphate of magnesia and soda . .	2·9
	8·0

It consists, then, of the following ingredients :—

Water	357·0
Vegetable fibre and animal matter .	135·0
Silica	3·2
Phosphate of lime . . . ·	0·4
Carbonate of lime	1·5
Phosphate of magnesia and soda .	2·9
. . .	500·0

Carbon	.	.	.	.	.	45·24
Hydrogen	.	.	.	.	.	6·88
Nitrogen (average)	.	.	.	.	4·00
Oxygen	.	.	.	.	.	30·30
Ashes	.	.	.	.	.	13·38

The inorganic matter contained in the excrements analyzed is nearly two per cent. less than that found by Berzelius; but the proportion always varies, according to the nature of the food.

It is quite certain that the vegetable constituents of the excrements with which we manure our fields cannot be entirely without influence upon the growth of the crops on them, for they will decay, and thus furnish carbonic acid to the young plants. But it cannot be imagined that their influence is very great, when it is considered that a good soil is manured only once every six or seven years, or once every eleven or twelve years, when sainfoin or lucern has been raised on it, that the quantity of carbon thus given to the land corresponds to only 5·8 per cent. of what is removed in the form of herbs, straw, and grain; and further, that the rain-water received by a soil contains much more carbon in the form of carbonic acid than these vegetable constituents of the manure.

The peculiar action, then, of the solid excrements is limited to their inorganic constituents, which thus restore to a soil that which is removed in the form of corn, roots, or grain. When we manure land with the dung of the cow or sheep, we supply it with silicate of potash and some salts of phosphoric acid. In human fæces we give it the phosphates of lime and magnesia; and in those of the horse, phosphate of magnesia, and silicate of potash. In the straw which has served as litter, we add a further quantity of silicate of potash and phosphates; which, if the straw be putrefied, are in exactly the same condition in which they were before being assimilated.

It is evident, therefore, that the soil of a field will alter but little, if we collect and distribute the dung carefully; a certain portion of the phosphates, however, must be lost every year, being removed from the land with the corn and cattle, and this portion will accumulate in the neighbourhood of large towns. The loss thus suffered must be compensated for in a well-managed farm, and this is partly done by allowing the fields to lie in grass. In Germany, it is considered that for every 100 acres of corn land, there must, in order to effect a profitable cultivation, be 20 acres of pasture-land, which produce annually, on an average, 500 lbs. of hay. Now, assuming that the ashes of the excrements of the animals fed with this hay amount to 6·82 per cent., then 341 lbs. of the silicate of lime and phosphates of magnesia and lime must be yielded by these excrements, and will in a certain measure compensate for the loss which the corn-land had sustained.

The absolute loss in the salts of phosphoric acid, which are not again replaced, is spread over so great an extent of surface, that it scarcely deserves to be taken account of. But the loss of phosphates is again replaced in the pastures by the ashes of the wood used in our houses for fuel.

We could keep our fields in a constant state of fertility by replacing every year as much as we remove from them in the form of produce; but an increase of fertility, and consequent increase of crop, can only be obtained when we add more to them than we take away. It will be found, that of two fields placed under conditions otherwise similar, the one will be most fruitful upon which the plants are enabled to appropriate more easily and in greater abundance those contents of the soil which are essential to their growth and development.

From the foregoing remarks it will readily be inferred,

that for animal excrements, other substances containing
their essential constituents may be substitut d. In Flan-
ders, the yearly loss of the necessary matters in the soil
is completely restored by covering the fields with ashes of
wood or bones, which may or may not have been lixi-
viated, and of which the greatest part consists of the phos-
phates of lime and magnesia. The great importance of
manuring with ashes has been long recognised by agri-
culturists as the result of experience. So great a value,
indeed, is attached to this material in the vicinity of Mar-
burg and in the Wetterau*, that it is transported as a
manure from the distance of 18 or 24 miles. Its use will
be at once perceived, when it is considered that the ashes,
after having been washed with water, contain silicate of
potash exactly in the same proportion as in straw (10 Si
O 3 + K O.), and that their only other constituents are
salts of phosphoric acid.

But ashes obtained from various kinds of trees are of
very unequal value for this purpose; those from oak-
wood are the least, and those from beech the most ser-
viceable. The ashes of oak-wood contain only traces of
phosphates, those of beech the fifth part of their weight,
and those of the pine and fir from 9 to 15 per cent. The
ashes of pines from Norway contain an exceedingly small
quantity of phosphates, namely, only 1·8 per cent. of
phosphoric acid. (Berthier.)

With every 100 lbs. of the lixiviated ashes of the beech
which we spread over a soil, we furnish as much phos-
phates as 460 lbs. of fresh human excrements could
yield. Again, according to the analysis of De Saussure,
100 parts of the ashes of the grain of wheat contain 82
parts of soluble, and 44·5 of insoluble phosphates, in all

* Two well-known agricultural districts; the first in Hesse-Cassel, the
second in Hesse-Darmstadt.

76·5 parts. Now the ashes of wheat-straw contain 11·5 per cent. of the same salts; hence with every 100 lbs. of the ashes of the beech, we supply a field with phosphoric acid sufficient for the production of 3820 lbs. of straw (its ashes being calculated at 4·3 per cent. De Saussure), or for 15-18000 lbs. of corn, the ashes of which amount, according to De Saussure, to 1·3 per cent.

Bone manure possesses a still greater importance in this respect. The primary sources from which the bones of animals are derived are, the hay, straw, or other substances which they take as food. Now if we admit that bones contain 55 per cent. of the phosphates of lime and magnesia (Berzelius), and that hay contains as much of them as wheat straw, it will follow that 8 lbs. of bones contain as much phosphate of lime as 1000 lbs. of hay or wheat-straw, and 2 lbs. of it as much as 1000 lbs. of the grain of wheat or oats. These numbers express pretty nearly the quantity of phosphates which a soil yields annually on the growth of hay and corn. Now the manure of an acre of land with 40 lbs. of bone-dust is sufficient to supply three crops of wheat, clover, potatoes, turnips, &c., with phosphates. But the form in which they are restored to a soil does not appear to be a matter of indifference. For the more finely the bones are reduced to powder, and the more intimately they are mixed with the soil, the more easily are they assimilated. The most easy and practical mode of effecting their division is to pour over the bones, in a state of fine powder, half of their weight of sulphuric acid diluted with three or four parts of water, and after they have been digested for some time, to add one hundred parts of water, and sprinkle this mixture over the field before the plough. In a few seconds, the free acids unite with the bases contained in the earth,

and a neutral salt is formed in a very fine state of division. Experiments instituted on a soil formed from grauwacke, for the purpose of ascertaining the action of manure thus prepared, have distinctly shown that neither corn, nor kitchen-garden plants, suffer injurious effects in consequence, but that on the contrary they thrive with much more vigour.

It has also been found that bones act more speedily and efficaciously after being boiled. This is probably owing to the removal of fatty matter, the presence of which impedes the putrefaction of the gelatin contained in them.

In the manufactories of glue, many hundred tons of a solution of phosphates in muriatic acid are yearly thrown away as being useless. It would be important to examine whether this solution might not be substituted for the bones. The free acid would combine with the alkalies in the soil, especially with the lime, and a soluble salt would thus be produced, which is known to possess a favourable action upon the growth of plants. This salt, muriate of lime (or chloride of calcium), is one of those compounds which attract water from the atmosphere with great avidity, and in dry lands might advantageously supply the place of gypsum in decomposing carbonate of ammonia, with the formation of sal-ammoniac and carbonate of lime. A solution of bones in muriatic acid placed on land in autumn or in winter would, therefore, not only restore a necessary constituent of the soil, and attract moisture to it, but would also give it the power to retain all the ammonia which fell upon it dissolved in the rain during the period of six months *.

* Immense quantities of bran are used in all print-works, for the purpose of clearing printed goods. After having served this purpose, it is

The ashes of brown coal and peat often contain silicate of potash, so that it is evident that these might completely replace one of the principal constituents of the dung of the cow and horse, and they contain also some phosphates. Indeed they are much esteemed in the Wetterau as manure for meadows and moist land.

It is of much importance to the agriculturist that he should not deceive himself respecting the causes which give the peculiar action to the substances just mentioned. It is known that they possess a very favourable influence on vegetation; and it is likewise certain that the cause of this is their containing a body, which, independently of the influence which it exerts by virtue of its form, porosity, and capability of attracting and retaining moisture, also assists in maintaining the vital processes in plants. If it be treated as an unfathomable mystery, the nature of this aid will never be known.

In medicine, for many centuries, the mode of action of all remedies was supposed to be concealed by the mystic veil of Isis; but now these secrets have been explained in a very simple manner. An unpoetical hand has pointed out the cause of the wonderful and apparently inexplicable healing virtues of the springs in Savoy, by which the inhabitants cured their goître; it was shown that they contain small quantities of iodine. In burnt sponges used for the same purpose, the same element was also detected. The extraordinary efficacy of Peruvian

thrown away. But the insoluble part of bran contains much phosphates of magnesia and soda; it would therefore be useful to preserve it as a manure. This has been done for some years in a farm with which I am connected, and its value as a manure has been found so great that it is much preferred to cow-dung. In some works this waste bran is heaped up into little hillocks, which might be disposed of as a manure, instead of being an annoyance on account of the space which it occupies.—Ed.

We may furnish a plant with carbonic acid, and all the materials which it may require; we may supply it with humus in the most abundant quantity; but it will not attain complete development unless nitrogen is also afforded to it; an herb will be formed, but no grain; even sugar and starch may be produced, but no gluten.

But when we give a plant nitrogen in considerable quantity, we enable it to attract with greater energy from the atmosphere the carbon which is necessary for its nutrition, when that in the soil is not sufficient; we afford to it a means of fixing the carbon of the atmosphere in its organism.

We cannot ascribe much of the power of the excrements of black cattle, sheep, and horses, to the nitrogen which they contain, for its quantity is too minute. But that contained in the fæces of man is proportionably much greater, although by no means constant. In the fæces of the inhabitants of towns, for example, who feed on animal matter, there is much more of this constituent than in those of peasants, or of such people as reside in the country. The fæces of those who live principally on bread and potatoes are similar in composition and properties to those of animals.

All excrements have in this respect a very variable and relative value. Thus those of black cattle and horses are of great use on soils consisting of lime and sand, which contain no silicate of potash and phosphates; whilst their value is much less when applied to soils formed of argillaceous earth, basalt, granite, porphyry, clinkstone, and even mountain-limestone, because all these contain potash in considerable quantity. In such soils human excrements are extremely beneficial, and increase their fertility in a remarkable degree; they are, of course, as

advantageous for other soils also; but for the manure of those first mentioned, the excrements of other animals are quite indispensable.

OF URINE.

We possess only one other natural source of manure which acts by its nitrogen, besides the faeces of animals, —namely, the urine of man and animals.

Urine is employed as manure either in the liquid state, or with the faeces which are impregnated with it. It is the urine contained in them which gives to the solid faeces the property of emitting ammonia,—a property which they themselves possess only in a very slight degree.

When we examine what substances we add to a soil by supplying it with urine, we find that this liquid contains in solution ammoniacal salts, uric acid (a substance containing a large quantity of nitrogen), and salts of phosphoric acid.

According to Berzelius, 1000 parts of human urine contain—

Urea	30·10
Free Lactic acid, Lactate of Ammonia, and animal matter not separable from them	17·14
Uric acid	1·00
Mucus of the bladder	0·32
Sulphate of Potash	3·71
Sulphate of Soda	3·16
Phosphate of Soda	2·94
Phosphate of Ammonia	1·65
Chloride of Sodium	4·45
Muriate of Ammonia	1·50
Phosphates of Magnesia and Lime	1·00
Silicious earth	0·03
Water	933·00
	1000·00

If we subtract from the above the urea, lactate of ammo-nia, free lactic acid, uric acid, the phosphate and muriate of ammonia; 1 per cent. of solid matter remains, consist-ing of inorganic salts, which must possess the same action when brought on a field, whether they are dis-solved in water or in urine. Hence the powerful influence of urine must depend upon its other ingredients, namely, the urea and ammoniacal salts. The urea in human urine exists partly as lactate of urea, and partly in a free state. (Henry.) Now when urine is allowed to putrefy spontaneously, that is, to pass into that state in which it is used as manure, all the urea in combination with lactic acid is converted into lactate of ammonia, and that which was free, into volatile carbonate of ammonia.

In dung-reservoirs well constructed and protected from evaporation, this carbonate of ammonia is retained in the state of solution, and when the putrefied urine is spread over the land, a part of the ammonia will escape with the water which evaporates, but another portion will be absorbed by the soil, if it contains either alumina or iron; but in general only the muriate, phosphate, and lactate of ammonia remain in the ground. It is these alone, therefore, which enable the soil to exercise a direct influence on plants during the progress of their growth, and not a particle of them escapes being absorbed by the roots.

On account of the formation of this carbonate of ammonia the urine becomes alkaline, although it is acid in its natural state. When it is lost by being volatilized in the air, which happens in most cases, the loss suffered is nearly equal to one half of the weight of the urine employed; so that if we fix it, that is, if we deprive it of its volatility, we increase its action two-fold. The exist-

ence of carbonate of ammonia in putrefied urine long
since suggested the manufacture of sal-ammoniac from
this material.   When the latter salt possessed a high
price, this manufacture was even carried on by the
farmer. For this purpose the liquid obtained from
dunghills was placed in vessels of iron, and subjected to
distillation ; the product of this distillation was converted
into muriate of ammonia by the common method. (De-
machy.)   But it is evident that such a thoughtless pro-
ceeding must be wholly relinquished, since the nitrogen
of 100 lbs. of sal-ammoniac (which contains 26 parts of
nitrogen) is equal to the quantity of nitrogen contained
in 1200 lbs. of the grain of wheat, 1480 lbs. of that of
barley, or 2755 lbs. of hay. (Boussingault.)

The carbonate of ammonia formed by the putrefaction
of urine, can be fixed or deprived of its volatility in many
ways.

If a field be strewed with gypsum, and then with
putrefied urine or the drainings of dunghills, all the car-
bonate of ammonia will be converted into the sulphate
which will remain in the soil.

But there are still simpler means of effecting this pur-
pose ;—gypsum, chloride of calcium, sulphuric or muriatic
acid, and super-phosphate of lime, are all substances of
a very low price, and completely neutralise the urine,
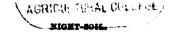converting its ammonia into salts which possess no
volatility.

If a basin, filled with concentrated muriatic acid, is
placed in a common necessary, so that its surface is in
free communication with the vapours which rise from
below, it becomes filled after a few days with crystals of
muriate of ammonia. The ammonia, the presence of
which the organs of smell amply testify, combines with

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the muriatic acid and loses entirely its volatility, and thick clouds or fumes of the salt newly formed hang over the basin.   In stables the same may be seen.   The ammonia that escapes in this manner is not only entirely lost, as far as our vegetation is concerned, but it works also a slow, though not less certain, destruction of the walls of the building.   For when in contact with the lime of the mortar, it is converted into nitric acid, which gradually dissolves the lime.   The injury thus done to a building by the formation of the soluble nitrates, has received (in Germany) a special name—salpeterfrass.

The ammonia emitted from stables and necessaries is always in combination with carbonic acid.   Carbonate of ammonia and sulphate of lime (gypsum) cannot be brought together at common temperatures, without mutual decomposition.   The ammonia enters into combination with the sulphuric acid, and the carbonic acid with the lime, forming compounds which are not volatile, and consequently destitute of all smell.   Now, if we strew the floors of our stables, from time to time, with common gypsum,-they will lose all their offensive smell, and none of the ammonia which forms can be lost, but will be retained in a condition serviceable as manure.

With the exception of urea, uric acid contains more nitrogen than any other substance generated by the living organism; it is soluble in water, and can be thus absorbed by the roots of plants, and its nitrogen assimilated in the form of ammonia, and of the oxalate, hydrocyanate, or carbonate of ammonia.

It would be extremely interesting to study the transformations which uric acid suffers in a living plant.   For the purpose of experiment, the plant should be made to grow in charcoal powder previously heated to redness,

and then mixed with pure uric acid. The examination of the juice of the plant, or of the component parts of the seed or fruit, would be a means of easily detecting the differences.

NIGHT-SOIL.

In respect to the quantity of nitrogen contained in excrements, 100 parts of the urine of a healthy man are equal to 1300 parts of the fresh dung of a horse, according to the analyses of Macaire and Marcet, and to 600 parts of those of a cow. Hence it is evident that it would be of much importance to agriculture if none of the human urine were lost. The powerful effects of urine as a manure are well known in Flanders*, but they are considered invaluable by the Chinese, who are the oldest agricultural people we know. Indeed so much value is attached to the influence of human excrements by these people, that laws of the state forbid that any of them should be thrown away, and reservoirs are placed in every house, in which they are collected with the greatest care. No other kind of manure is used for their corn-fields†.

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* See the article "On the Agriculture of the Netherlands," *Journ. Royal Agri. Soc.*, vol. ii. part 1, page 43, for much interesting information on this subject.

† Davis, in his *History of China*, states that every substance convertible into manure is diligently husbanded. "The cakes that remain after the expression of their vegetable oils, horns and hoofs reduced to powder, together with soot and ashes, and the contents of common sewers, are much used. The plaster of old kitchens, which in China have no chimneys but an opening at the top, is much valued; so that they will sometimes put a new plaster on a kitchen for the sake of the old." The ammonia contained in the fuel forms nitrate of lime with the lime in the mortar. "All sorts of hair are used as a manure, and barbers' shavings are carefully appropriated to that purpose. The annual produce

China is the birth-place of the experimental art; the incessant striving after experiments has conducted the Chinese a thousand years since to discoveries, which

must be considerable in a country where some hundred millions of heads are kept constantly shaved. Dung of all animals, but more especially night-soil, is esteemed above all others. Being sometimes formed into cakes, it is dried in the sun, and in this state becomes an object of sale to farmers, who dilute it previous to use. They construct large cisterns or pits, lined with lime plaster, as well as earthen tubs, sunk into the ground, with straw over them to prevent evaporation, in which all kinds of vegetables and animal refuse are collected. These being diluted with a sufficient quantity of liquid, are left to undergo the putrefactive fermentation, and then applied to the land. In the case of everything except rice, the Chinese seem to manure the plant itself rather than the soil, supplying it copiously with their liquid preparation."

"The Chinese husbandman," observes Sir G. Staunton, (*Embassy,* vol. ii.,) "always steeps the seeds he intends to sow in liquid manure, until they swell, and germination begins to appear, which experience has taught him will have the effect of hastening the growth of plants, as well as of defending them against the insects hidden in the ground in which the seeds are sown. To the roots of plants and fruit-trees, the Chinese farmer applies liquid manure likewise."

Lastly, we extract the following from a communication to Professor Webster, of Harvard College, United States :—" Human urine is, if possible, more husbanded by the Chinese than night-soil for manure; every farm, or patch of land for cultivation, has a tank, where all substances convertible into manure are carefully deposited, the whole made liquid by adding urine in the proportion required, and invariably applied in that state." This is exactly the process followed in the Netherlands : see *Outlines of Flemish Husbandry,* page 22.

" The business of collecting urine and night-soil employs an immense number of persons, who deposit tubs in every house in the cities for the reception of the urine of the inmates, which vessels are removed daily, with as much care as our farmers remove their honey from the hives."

When we consider the immense value of night-soil as a manure, it is quite astounding that so little attention is paid to preserve it. The quantity is immense which is carried down by the drains in London to the River Thames, serving no other purpose than to pollute its waters. It has been shown, by a very simple calculation, that the value of the manure thus lost amounts annually to several *millions of pounds sterling.* A substance, which by its putrefaction generates miasmata, may, by artificial means, be rendered totally inoffensive, inodorous, and transportable, and yet prejudice prevents these means being resorted to.—ED.

have been the envy and admiration of Europeans for centuries, especially in regard to dyeing and painting, and to the manufactures of porcelain, silk, and colours for painters. These we were long unable to imitate, and yet they were discovered by them without the assistance of scientific principles; for in the books of the Chinese we find recipes and directions for use, but never explanations of processes.

Half a century sufficed to Europeans not only to equal but to surpass the Chinese in the arts and manufactures, and this was owing merely to the application of correct principles deduced from the study of chemistry. But how infinitely inferior is the agriculture of Europe to that of China! The Chinese are the most admirable gardeners and trainers of plants, for each of which they understand how to prepare and apply the best-adapted manure. The agriculture of their country is the most perfect in the world; and there, where the climate in the most fertile districts differs little from the European, very little value is attached to the excrements of animals. With us, thick books are written, but no experiments instituted; the quantity of manure consumed by this and that plant is expressed in hundredth parts, and yet we know not what manure is!

If we admit that the liquid and solid excrements of man amount on an average to $1\frac{1}{4}$ lb. daily ($\frac{1}{4}$ lb. of urine and $\frac{1}{4}$ lb. fæces), and that both taken together contain 3 per cent. of nitrogen, then in one year they will amount to 547 lbs., which contain 16·41 lbs. of nitrogen, a quantity sufficient to yield the nitrogen of 800 lbs. of wheat, rye, oats, or of 900 lbs. of barley. (Boussingault.)

This is much more than it is necessary to add to an acre of land in order to obtain, with the assistance of the

nitrogen absorbed from the atmosphere, the richest pos-
sible crop every year.   Every town and farm might thus
supply itself with the manure, which besides containing
the most nitrogen, contains also the most phosphates ;
and if rotation of the crops were adopted, they would
be most abundant.   By using, at the same time, bones
and the lixiviated ashes of wood, the excrements of
animals might be completely dispensed with.

When human excrements are treated in a proper
manner, so as to remove the moisture which they contain
without permitting the escape of ammonia, they may be
put into such a form as will allow them to be transported
even to great distances.

This is already attempted in many towns, and the pre-
paration of night-soil for transportation constitutes not an
unimportant branch of industry.   But the manner in
which this is done is the most injudicious which could
be conceived.   In Paris, for example, the excrements are
preserved in the houses in open casks, from which they
are collected and placed in deep pits at Montfaucon, but
are not sold until they have attained a certain degree of
dryness by evaporation in the air.   But whilst lying in
the receptacles appropriated for them in the houses, the
greatest part of their urea is converted into carbonate of
ammonia ; lactate and phosphate of ammonia are also
formed, and the vegetable matters contained in them
putrefy ; all their sulphates are decomposed, whilst their
sulphur forms sulphuretted hydrogen and hydro-sulphate
of ammonia.   The mass, when dried by exposure to the
air, has lost more than half of the nitrogen which the
excrements originally contained ; for the ammonia escapes
into the atmosphere along with the water which evapo-
rates ; and the residue now consists principally of phos-

phate of lime, with phosphate and lactate of ammonia, and small quantities of urate of magnesia and fatty matter. Nevertheless it is still a very powerful manure, but its value as such would be twice or four times as great, if the excrements before being dried were neutralised with a cheap mineral acid.

In other manufactories of manure the night-soil, whilst still soft, is mixed with the ashes of wood, or with earth, both of which substances contain a large quantity of caustic lime, by means of which a complete expulsion of all its ammonia is effected, and it is completely deprived of smell. But such a residue applied as manure can act only by the phosphates which it still contains, for all the ammoniacal salts have been decomposed and their ammonia expelled.

The preparation of night-soil is now carried on in London to a considerable extent. Owing to the variable nature of the climate, artificial means are employed in its desiccation. The night-soil, after being subjected to one or other of the modes of treatment described below, is placed upon iron plates heated by means of furnaces.

As soon as the night-soil is collected, it is placed in large broad trenches, until a sufficient quantity is accumulated for the purposes of the manufacturer. But here it undergoes the same process of putrefaction to which allusion has been made, and acquires a peculiarly offensive smell from the evolution of sulphuretted hydrogen and other gases, which are observed to escape. Unless some means be employed, at this stage of the process, to retain the ammonia, it escapes into the atmosphere in the form of a carbonate. Various methods have been proposed to effect this purpose. Some manufacturers mix the night-soil with chloride of lime, and evaporate off the water by

the aid of heat. This possesses the advantage of depriving the excrements of smell, and at the same time partially fixes the ammonia which would otherwise escape. Chloride of lime always contains a considerable excess of lime; hence part of the ammonia contained in the night-soil is expelled by means of it.

More simple and economical methods might be employed. A patent, which has been taken out for the preparation of this useful manure states in its specification, that the night-soil is to be mixed with calcined mud and finely-divided charcoal. By this means, the smell is completely and instantaneously removed, and the ammonia retained by virtue of the affinity, which alumina and charcoal exert for that compound. This plan is both simple and efficacious, but the ammonia is apt to be expelled by the application of the heat employed in drying the manure. The addition of a cheap mineral acid to the night-soil, before admixture with these ingredients, would materially improve both of the above processes.

It would no doubt be highly advantageous in the preparation of manures, to prepare them so that they contained all the ingredients necessary for the supply of the plants to which they are applied. But these will of course vary according to the nature of the soils and plants for which they are intended. Thus bones, soap-boilers' waste, nitrate of soda, and ashes of wood, will often be found to form advantageous additions. Sulphate of magnesia (Epsom salts) would, in most cases, form an invaluable ingredient in prepared night-soil. (See Supplementary Chapter on Soils.) The products of the decomposition proceeding from the action of this salt upon night-soil are, sulphate of ammonia, phosphate of magnesia, and the double phosphate of magnesia and ammonia. Now,

all these salts exert a very favourable influence upon vegetation, and the phosphate of magnesia is, in many cases, perfectly indispensable to the growth and development of certain plants. This suggestion is well worthy of the attention of the farmer.

Perhaps the best and most practical method of fixing the ammoniacal salts of urine and night-soil, is to mix them with the ashes of peat or coal. When the latter are employed, care must be taken to select such as are of a porous, earthy consistence. The ashes both of peat and coal contain in general magnesia ; hence their value as an ingredient of prepared night-soil. When magnesia is not present, it will be necessary to add some magnesian limestone or Epsom salts. The night-soil should be mixed thoroughly with the ashes, and exposed to the air to dry. The disagreeable smell is thus quickly removed, and a pulverulent manure obtained, which can be applied to the fields with facility.

Animal charcoal, which has served for the discoloration of sugar, possesses the property of removing the offensive smell of night-soil, and is of itself an admirable manure. In cases where it can be procured with facility, it will be found to add to the efficacy of the latter.

GUANO.

The sterile soils of the South American coast are manured with a substance called guano, consisting of urate of ammonia and other ammoniacal salts, by the use of which a luxuriant vegetation and the richest crops are obtained. Guano has lately been imported in considerable quantity into Liverpool and several other English ports, and is now experimentally-employed as a manure

by English agriculturists. A consideration of its com-
position and mode of action cannot, therefore, fail to be
acceptable.

Much speculation has arisen as to the true origin of
Guano*, but the most certain proof is now afforded, that it
has been produced by the accumulation of the excrements
of innumerable sea-fowl which inhabit the islands upon
which it is found. Meyen, the latest writer upon this
subject, completely coincides with this opinion; for he
says†—" Their number is Legion ; they completely cloud
the sun, when they rise from their resting-place in the
morning in flocks of miles in length." Yet, notwithstand-
ing their great number, thousands of years must have
elapsed, before the excrements could have accumulated
to such a thickness as they possess at present. Guano
has been used by the Peruvians as a manure since the
twelfth century; and its value was considered so inestima-
ble, that the government of the Incas issued a decree, by
which capital punishment was inflicted upon any person
found destroying the fowl on the Guano islands. Over-
seers were also appointed over each province, for the pur-
pose of insuring them further protection. Under this
state of things, the accumulation of the excrements may
have well taken place. All those regulations are, how-
ever, now abandoned‡. Rivero states that the annual con-
sumption of guano for the purposes of agriculture amounts
to 40,000 *fanegas*. The increase of crops obtained by the
use of guano is very remarkable. According to the same
authority, the crop of potatoes is increased 45 times by
means of it, and that of maize 35 times. The manner of

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* Much of the information regarding Guano here given is extracted from
a paper in *Liebig's Annalen*, xxxvii. 3, 291.

† *Reise um die Erde*, B. i. S. 434.

‡ Garcilaso, *Historie de los Yncas*, vol. i. p. 134.

applying the manure is singular.   Thus in Arica, where
so much pepper (*Capsicum baccatum*) is cultivated, each
plant is manured three times: first upon the appearance
of the roots, second upon that of the leaves, and lastly
upon the formation of the fruit. (Humboldt.) From this
it will be observed, that the Peruvians follow the plan
of the Chinese, in manuring the plant rather than the
soil.   The composition of guano points out how admira-
bly it is fitted for a manure ; for not only does it contain
ammoniacal salts in abundance, but also those inorganic
constituents which are indispensable for the development
of plants.

   The most recent analysis is that of Völckel, who found
it to consist of

Urate of Ammonia	9·0
Oxalate of Ammonia	10·6
Oxalate of Lime	7·0
Phosphate of Ammonia	6·0
Phosphate of Magnesia and Ammonia	2·6
Sulphate of Potash	5·5
Sulphate of Soda	3·8
Sal-ammoniac	4·2
Phosphate of Lime	14·3
Clay and Sand	4·7
Organic substances not estimated, containing 12 per cent. of matter insoluble in water. Soluble Salts of Iron in small quantity. Water	32·3
	100·0

   It will be observed from the above analysis, that urea
does not enter into the composition of guano.   The uric
acid of the excrements must have been decomposed into
oxalic acid and ammonia.   The soluble substances con-
tained in guano amount to half its weight.   It is singular
that we do not find nitrates amongst the ingredients which
compose it.   Guano possesses a urinous smell, precisely

similar to that perceived on the evaporation of urine.
The experiments upon the efficacy of this manure in
England have not yet been sufficiently multiplied to
enable us to judge whether or not its virtues have been
overrated.

The corn-fields in China receive no other manure than
human excrements. But we cover our fields every year
with the seeds of weeds, which from their nature and form
pass undigested along with the excrements through
animals, without being deprived of their power of germi-
nation, and yet it is considered surprising that where they
have once flourished, they cannot again be expelled by
all our endeavours : we think it very astonishing, while
we really sow them ourselves every year. A famous
botanist, attached to the Dutch embassy to China, could
scarcely find a single plant on the corn-fields of the
Chinese, except the corn itself.*

The urine of horses contains less nitrogen and phos-
phates than that of man. According to Fourcroy and
Vauquelin it contains only five per cent. of solid matter,
and in that quantity only 0·7 of urea ; whilst 100 parts of
the urine of man contain more than four times as much.

The urine of a cow is particularly rich in salts of
potash ; but according to Rouelle and Brande, it is almost
destitute of salts of soda. The urine of swine contains a
large quantity of the phosphate of magnesia and ammo-
nia ; and hence it is that concretions of this salt are so
frequently found in the urinary bladders of these animals.

It is evident that if we place the solid or liquid excre-
ments of man or the liquid excrements of animals on our
land, in equal proportion to the quantity of nitrogen
removed from it in the form of plants, the sum of this

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* Ingenhouss on the Nutrition of Plants, page 129 (German edition).

element in the soil must increase every year; for to the quantity which we thus supply, another portion is added from the atmosphere. The nitrogen which we export as corn and cattle, and which is thus absorbed by large towns, serves only to benefit other farms, if we do not replace it. A farm which possesses no pastures, and not fields sufficient for the cultivation of fodder, requires manure containing nitrogen to be imported from elsewhere, if it is desired to produce a full crop. In large farms, the annual expenditure of nitrogen is completely replaced by means of the pastures.

The only absolute loss of nitrogen, therefore, is limited to the quantity which man carries with him to his grave; but this at the utmost cannot amount to more than 3 lbs. for every individual, and is being collected during his whole life. Nor is this quantity lost to plants, for it escapes into the atmosphere as ammonia during the putrefaction and decay of the body.

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

From the preceding remarks it must be evident, that the greatest value should be attached to the liquid excrements of man and animals, when a manure is desired which shall supply nitrogen to the soil. The greatest part of a superabundant crop, or, in other words, the increase of growth which is in our power, can be obtained exclusively by their means.

When it is considered that with every pound of ammonia which evaporates, a loss of 60 lbs. of corn is sustained, and that with every pound of urine a pound of wheat might be produced, the indifference with which

these liquid excrements are regarded is quite incomprehensible. In most places only the solid excrements impregnated with the liquid are used, and the dunghills containing them are protected neither from evaporation nor from rain. The solid excrements contain the insoluble, the liquid all the soluble phosphates, and the latter contain likewise all the potash which existed as organic salts in the plants consumed by the animals.

Fresh bones, wool, hair, hoofs, and horn, are manures containing nitrogen as well as phosphates, and are consequently fit to aid the process of vegetable life. All animal matter is fitted for the same purpose. Butchers' offal, such as the blood and intestines of animals, form a most powerful manure. It is in general necessary to dilute such manure by admixture with other kinds less powerful in their action.

One hundred parts of dry bones contain from 32 to 33 per cent. of dry gelatine; now supposing this to contain the same quantity of nitrogen as animal glue, viz., 5.28 per cent., then 100 parts of bones must be considered as equivalent to 250 parts of human urine.

Bones may be preserved unchanged for thousands of years, in dry or even in moist soils, provided the access of rain is prevented; as is exemplified by the bones of antediluvian animals found in loam or gypsum, the interior parts being protected by the exterior from the action of water. But they become warm when reduced to a fine powder, and moistened bones generate heat and enter into putrefaction; the gelatine which they contain is decomposed, and its nitrogen converted into carbonate of ammonia and other ammoniacal salts, which are retained in a great measure by the powder itself. (Bones burnt till quite white, and recently heated to redness, absorb · 7·5 times their volume of pure ammoniacal gas.)

ARTIFICIAL MANURES.

WE have now examined the action of the animal or natural manures upon plants; but it is evident that if artificial manures contain the same constituents, they will exercise a similar action upon the plants to which they are applied. We shall only notice here one or two of those principally employed.

Since it has been ascertained that animal manures act (as far as the formation of *organic* matter is concerned) only by the ammonia which they contain, attention has been devoted by chemists to discover a more economical means of presenting this ammonia to plants. The water which distils from the retorts in the preparation of coal gas is strongly charged with this alkali, but is at the same time mixed with tar and other empyreumatic impurities. It has been customary to allow the tarry matter to subside, and decant off the clear, supernatant liquor. This liquor, being diluted to such a degree as to be tasteless, is applied as a manure to the field.

Now, the ammoniacal liquor of the gas-works contains the ammonia in the form of carbonate and hydro-sulphate of ammonia (sulphuret of ammonium). The latter compound is a deadly poison to vegetables, nor can we conceive that by dilution its properties can be changed. The carbonate of ammonia is volatile, and escapes into the atmosphere. To obviate this latter inconvenience and render it more transportable, it has been proposed to convert the carbonate into the sulphate, by means of gypsum *. But this does not remove the hydro-sulphate. A more simple and efficacious method is to add a solution of sulphate of iron (the green vitriol of the shops) to the

liquor, until no further precipitation ensues.   Sulphuret
and carbonate of iron are thus formed, and the whole of
the ammonia enters into combination with the sulphuric
acid, and forms sulphate of ammonia.·   Care must be
taken to avoid too great an excess of sulphate of iron;
and the liquor thus prepared should be freely exposed to
the air to promote the oxidation.

The liquor still, however, contains empyreumatic mat-
ters, which are injurious to plants.   These may be
removed by evaporating the liquor to dryness, and heat-
ing the residue to incipient redness.   By this means they
are rendered insoluble, and the sulphate of ammonia is
not affected, unless the heat has been carried too far.
The liquor properly diluted has been found very advan-
tageous, even without the removal of the empyreumatic
matter.

Nitrate of soda has lately engaged much attention, and
is supposed to exert its favourable action upon vegetation
by yielding nitrogen to those of their constituents which
contain it.   The experiments which have hitherto been
instituted with this manure do not warrant us in con-
cluding with positive certainty that it is the nitrogen
alone to which it owes its efficacy, but they certainly
render this a plausible explanation of its virtues.
Thus Mr. Pusey, the late able president of the Royal
Agricultural Society, has shown, that the same effects
are produced by putrefied urine, soot, gas-liquor, and
nitrate of soda*.   Now the three former act by virtue of
the ammonia which enters into their composition.   The
usual effects produced by these and nitrate of soda are
to increase the intensity of the green colouring matter,
to augment the quantity of straw, but to produce a light

* Journal of the Royal Agricultural Society, vol. ii p. 143.

grain. Mr. Hyett[*] has communicated the results of an analysis of two samples of wheat grown under similar circumstances, one of which had been treated with nitre, the other not. The former contained 28·25 per cent. of gluten, and 1·375 of albumen; the latter only 19 per cent. of gluten, and 0·62 of albumen. Here the azotised matters appear to have considerably increased in quantity. There is nothing opposed to the supposition that nitric acid may be decomposed by plants, and its nitrogen assimilated. We find that vegetables possess the power of decomposing carbonic acid, and of appropriating its carbon for their own use. Now this acid is infinitely more difficult to decompose than nitric acid. But there are other circumstances which oppose the adoption of the view that nitrate of soda acts by virtue of the nitrogen which enters into its composition. Were this the case, the action should be more uniform than it has hitherto been found to be. On some soils the salt does not possess the smallest influence; whilst on others it affords great benefit. We can only furnish an explanation of this seeming caprice by a reference to the chemical composition of the soil upon which it is applied. If the advantages attending the application of nitrate of soda are due to the alkaline base which it contains, then it is evident that this manure can be of small value on soils containing a quantity of alkalies sufficient for the purposes of the plants grown upon them; whilst on the other hand, such as are deficient in these must experience benefit through its means[†]. In

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[*] Journal of the Royal Agricultural Society, vol. ii. p. 143.

[†] General Sir Howard Elphinstone informs me that he found carbonate of soda (soda ash) an excellent manure for his land. The crops obtained by means of it presented the same general characters as those manured with nitrate of potash, and exhibited a greater intensity of colour. If this is

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usual effects produced by these and nitrate of soda are
to increase the intensity of the green colouring matter,
to augment the quantity of straw, but to produce a light

* Journal of the Royal Agricultural Society, vol. ii p. 123.

grain. Mr. Hyett[*] has communicated the results of an analysis of two samples of wheat grown under similar circumstances, one of which had been treated with nitre, the other not. The former contained 23·25 per cent. of gluten, and 1·375 of albumen; the latter only 19 per cent. of gluten, and 0·62 of albumen. Here the azotised matters appear to have considerably increased in quantity. There is nothing opposed to the supposition that nitric acid may be decomposed by plants, and its nitrogen assimilated. We find that vegetables possess the power of decomposing carbonic acid, and of appropriating its carbon for their own use. Now this acid is infinitely more difficult to decompose than nitric acid. But there are other circumstances which oppose the adoption of the view that nitrate of soda acts by virtue of the nitrogen which enters into its composition. Were this the case, the action should be more uniform than it has hitherto been found to be. On some soils the salt does not possess the smallest influence; whilst on others it affords great benefit. We can only furnish an explanation of this seeming caprice by a reference to the chemical composition of the soil upon which it is applied. If the advantages attending the application of nitrate of soda are due to the alkaline base which it contains, then it is evident that this manure can be of small value on soils containing a quantity of alkalies sufficient for the purposes of the plants grown upon them; whilst on the other hand, such as are deficient in these must experience benefit through its means[†]. In

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certain cases in which nitrate of soda ·has failed, nitrate of potash (common saltpetre) has been very successful. Analyses of wheat grown with nitrate of soda and nitrate of potash would be of interest, in order to determine whether a mutual substitution of their respective bases is effected. It is to be hoped that future experiments will throw more light upon the action of this interesting manure, for theory cannot be satisfied with those already existing. It has been usual to employ a less quantity by weight of nitrate of potash than of nitrate of soda. This procedure seems rather empirical, for unless sanctioned by experience, it would à priori appear to be better to add the greatest quantity of that salt which possesses the highest equivalent. Now the equivalent of nitrate of potash is considerably higher than that of nitrate of soda.

Charcoal in a state of powder must be considered as a very powerful means of promoting the growth of plants on heavy soils, and particularly on such as consist of argillaceous earth*.

Ingenhouss proposed dilute sulphuric acid as a means of increasing the fertility of a soil. Now, when this acid is sprinkled on calcareous soils, gypsum (sulphate of lime) is immediately formed, which of course prevents the necessity of manuring the soils with this material. 100 parts of concentrated sulphuric acid diluted with from 800 to 1000 parts of water, are equivalent to 176 parts of gypsum.

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found uniformly to be the case, it will very much strengthen the supposition that the action of nitrate of soda is due to its alkaline constituent.—ED.

* For much valuable information on the subject of manures, see "Agricultural Chemistry," vol. viii. of Sir H. Davy's collected Works.

SUPPLEMENTARY CHAPTER.

ON THE CHEMICAL CONSTITUENTS OF SOILS.

THE fertility of a soil is much influenced by its physical properties, such as its porosity, colour, attraction for moisture, or state of disintegration. But independently of these conditions, the fertility depends upon the chemical constituents of which the soil is composed.

We have already shown, at considerable length, that those alkalies, earths, and phosphates, which constitute the ashes of plants, are perfectly indispensable for their development; and that plants cannot flourish upon soils from which these compounds are absent. The necessity of alkalies for the vital processes of plants will be obvious, when we consider that almost all the different families of plants are distinguished by containing certain acids, differing very much in composition; and further, that these acids do not exist in the juice in an isolated state, but generally in combination with certain alkaline or earthy bases. The juice of the vine contains tartaric acid, that of the sorrel, oxalic acid. It is quite obvious that a peculiar action must be in operation in the organism of the vine and sorrel, by means of which the generation of tartaric and oxalic acid is effected; and also that the same action must exist in all plants of the same genus. A similar cause forces corn-plants to extract silicic acid from the soil. The number of acids found in different

plants is very numerous, but the most common are those
which we have already mentioned ; to which may be added
acetic, malic, citric, aconitic, maleic, kinovic acids, &c.

When we observe that the proper acids of each family
of plants are never absent from it, we must admit that the
plants belonging to that family could not attain perfec-
tion, if the generation of their peculiar acids were pre-
vented. Hence, if the production of tartaric acid in the
vine were rendered impossible, it could not produce grapes,
or in other words, would not fructify. Now the generation
of organic acids is prevented in the vine, and, indeed, in
all plants which yield nourishment to men and animals,
when alkalies are absent from the soil in which they grow.
The organic acids in plants are very rarely found in a free
state ; in general, they are in combination with potash,
soda, lime, or magnesia. Thus, silicic acid is found as
silicate of potash ; acetic acid as acetate of potash, or soda ;
oxalic acid as oxalate of potash, soda, or lime ; tartaric
acid as bitartrate of potash, &c. The potash, soda, lime,
and magnesia in these plants are, therefore, as indispensa-
ble for their existence, as the carbon from which their
organic acids are produced.

In order not to form an erroneous conclusion regarding
the processes of vegetable nutrition, it must be admitted
that plants require certain salts for the sustenance of their
vital functions, the acids of which salts exist either in the
soil (such as silicic or phosphoric acids) or are generated
from nutriment derived from the atmosphere. Hence, if
these salts are not contained in the soil, or if the bases
necessary for their production be absent, they cannot be
formed ; or in other words, plants cannot grow in such a
soil. The juice, fruit, and leaves of a plant cannot attain
maturity, if the constituents necessary for their formation

are wanting, and salts must be viewed as such. These salts
do not, however, occur simultaneously in all plants. Thus,
in saline plants, soda is the only alkali found; in corn plants,
lime and potash form constituents. Several contain both
soda and potash, some both potash and lime; whilst others
contain potash and magnesia. The acids vary in a similar
manner. Thus one plant may contain phosphate of lime;
a second, phosphate of magnesia; a third, an alkali com-
bined with silicic acid, and a fourth, an alkali in combina-
tion with a vegetable acid. The respective quantities of
the salts required by plants are very unequal. The apti-
tude of a soil to produce one, but not another kind of
plant, is due to the presence of a base which the former
requires, and the absence of that indispensable for the
development of the latter. Upon the correct knowledge
of the bases and salts requisite for the sustenance of each
plant, and of the composition of the soil upon which it
grows, depends the whole system of a rational theory of
agriculture; and that knowledge alone can explain the pro-
cess of fallow, or furnish us with the most advantageous
methods of affording plants their proper nourishment.

Give—so says the rational theory—to one plant such
substances as are necessary for its development, but spare
those which are not requisite, for the production of other
plants that require them.

It is the same with regard to these bases as it is with
the water which is necessary for the roots of various
plants. Thus, whilst one plant flourishes luxuriantly in
an arid soil, a second requires much moisture, a third
finds necessary this moisture at the commencement of its
development, and a fourth (such as potatoes) after the
appearance of the blossom. It would be very erroneous
to present the same quantity of water to all plants indis-

criminately. Yet this obvious principle is lost sight of in the manuring of plants. An empirical system of agriculture has administered the same kind of manures to all plants; or when a selection has been made, it was not based upon a knowledge of their peculiar characters or composition.

The cost of labour in England has given rise to the production of much ingenuity in the invention of machines, which have produced improvements in the mode of application of manures. In order to use these with advantage, pulverulent manures are employed, instead of the common stable manure, which is generally mixed with much straw.

The necessity for such forms of manure naturally suggested the employment of bone dust, dried dung, lime, ashes, &c. Now, although by these means the necessary phosphates are furnished to a soil, and solid animal excrements rendered unnecessary, they have led to the neglect of the liquid excrements, that is, of the urine of men and animals, which is thus completely lost to agriculture. For although the meadows receive, during autumn and winter, when cattle are fed upon them, the solid and liquid excrements of these animals, yet the urine of man, into which all the nitrogenous constituents of animals are finally deposited, is completely lost to the fields. This most important of all manures, so properly estimated in Flanders, Germany, and China, is altogether lost to the English agriculturist. In large towns it is either allowed to run into the rivers, or sink into the ground in such a manner as to be of no benefit to the vegetable kingdom.

The most important growth in England is that of wheat; then of barley, oats, beans, and turnips. Potatoes are only cultivated to a great extent in certain localities;

rye, beet-root, and rape-seed, not very generally. Lucern is only known in a few districts, whilst red clover is found universally. Now, the selection of inorganic manures for these plants may be fixed upon by an examination of the composition of their ashes. Thus wheat must be cultivated in a soil rich in silicate of potash. If this soil is formed from feldspar, mica, basalt, clinkstone, or indeed of any minerals which disintegrate with facility, crops of wheat and barley may be grown upon it for many centuries in succession. But, in order to support an uninterrupted succession, the annual disintegration must be sufficiently great to render soluble a quantity of silicate of potash sufficient for the supply of a full crop of wheat or barley. If this is not the case, the soil must either be allowed to lie fallow from time to time, or plants may be cultivated upon it which contain little silicate of potash, or the roots of which are enabled to penetrate deeper into the soil than corn plants in search of this salt. During this interval of repose, the materials of the soil disintegrate, and potash in a soluble state is liberated on the layers exposed to the action of the atmosphere. When this has taken place, rich crops of wheat may be again expected.

The alkaline phosphates, as well as the phosphates of magnesia and lime, are necessary for the production of all corn-plants. Now, bones contain the latter, but none of the former, salts. These must, therefore, be furnished by means of night-soil, or of urine, a manure which is particularly rich in them *. Wood ashes have been found very useful for wheat in calcareous soils; for these

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* It has been already stated that bran contains phosphate of soda and phosphate of magnesia, so that it is useful as a manure where phosphates are desired.—ED.

ashes contain both phosphate of lime and silicate of potash. In like manner stable manure and night-soil render clayey soils fertile, by furnishing the magnesia in which they are deficient. The ashes of all kinds of herbs and decayed straw are capable of replacing wood ashes.

A compost manure, which is adapted to furnish all the inorganic matters to wheat, oats, and barley, may be made by mixing equal parts of bone dust and a solution of silicate of potash (known as *soluble glass* in commerce), allowing this mixture to dry in the air, and then adding 10 or 12 parts of gypsum, with 16 parts of common salt. Such a compost would render unnecessary the animal manures, which act by their inorganic ingredients. According to Berthier, 100 parts of the ashes of wheat straw contain—

Of matter soluble in water	9·0
Of matter insoluble in water	81·0

Now 100 parts of the soluble matter contain—

Carbonic acid	a trace
Sulphuric acid	2·0
Muriatic acid	13·0
Silica	35·0
Potash and Soda	50·0
	100·0

100 parts of the insoluble matter contain—

Carbonic acid	0
Phosphoric acid	1·2
Silica	75·0
Lime	5·8
Oxide of Iron and Charcoal	10·0
Potash	8·0
	100·0

The silicate of potash employed in the preparation of the compost described above, must not deliquesce on

exposure to the air, but must give a gelatinous consistence to the water in which it is dissolved, and dry to a white powder by exposure. It is only attractive of moisture when an excess of potash is present, which is apt to exert an injurious influence upon the tender roots of plants. In those cases where silicate of potash cannot be procured, a sufficiency of wood ashes will supply its place*.

All culinary vegetables, but particularly the cruciferæ, such as mustard, (sinapis alba and nigra,) contain sulphur in notable quantity. The same is the case with turnips, the different varieties of rape, cabbage, celery, and red clover. These plants thrive best in soils containing sulphates; hence if these salts do not form natural constituents of the soil, they must be introduced as manure. Sulphate of ammonia is the best salt for this purpose. It is most easily procured by the addition of gypsum or sulphate of iron† (green vitriol) to putrefied urine.

Horn, wool, and hoofs of cattle, contain sulphur as a constituent, so that they will be found a valuable manure when administered with soluble phosphates, (with urine, for example.)

Phosphate of magnesia and ammonia forms the prin-

* In some parts of the grand-duchy of Hesse, where wood is scarce and dear, it is customary for the common people to club together and build baking ovens, which are heated with straw instead of wood. The ashes of this straw are carefully collected and sold every year at very high prices. The farmers there have found by experience that the ashes of straw form the very best manure for wheat; although it exerts no influence on the growth of fallow-crops (potatoes or the leguminosæ, for example). The stem of wheat grown in this way possesses an uncommon strength. The cause of the favourable action of these ashes will be apparent, when it is considered that all corn-plants require silicate of potash; and that the ashes of straw consist almost entirely of this compound.—ED.

† If sulphate of iron be employed, it ought not to be added in great excess, and the urine must be exposed to the air for some time after, for the purpose of converting the iron into the peroxide. A salt of the protoxide of iron is injurious to vegetation.

nished to it. Thus it has been found that in soils defi-
cient in potash, the nitrates of soda or potash have been
very advantageous; whilst those, on the other hand,
which contain a sufficiency of alkalies, have experienced
no beneficial effects through their means. In the appli-
cation of manures to soils we should be guided by the
general composition of the ashes of plants, whilst the
manure applied to a particular plant ought to be selected
with reference to the substances which it demands for its
nourishment. In general, a manure should contain a
large quantity of alkaline salts, a considerable proportion
of phosphate of magnesia, and a smaller proportion of
phosphate of lime; azotised manure and ammoniacal
salts cannot be too frequently employed.

In the following part of this chapter I shall describe
a number of analyses of soils executed by Sprengel,
together with observations on their sterility and fertility,
as stated by that distinguished agriculturist. It is unne-
cessary to describe the *modus operandi* used in the analyses
of these soils, for this kind of research will never be made
by farmers, who must apply to the professional chemist,
if they wish for information regarding the composition of
their soils.

Under the term *surface-soil*, we mean that portion of
soil which is on the surface; whilst by *subsoil* we mean
that which is below the former, and out of reach of the
ordinary plough.

CHEMICAL COMPOSITION OF CERTAIN SOILS, ACCORDING TO ANALYSIS.

1. Surface-soil (A) a good loamy soil, from the
vicinity of Gandersheim. It is remarkable for producing
uncommonly fine red clover when manured with gypsum.

(B) is an analysis of the subsoil. 100 parts contain :—

	(A)	(B)
Silica, with fine siliceous sand	91·331	93·883
Alumina	1·344	1·944
Peroxide of iron, with a little protoxide	1·562	2·226
Peroxide of manganese	0·082	0·320
Magnesia and silica, in combination with sulphuric acid and humus	0·800	0·720
Magnesia, with silica and humic acid combined	0·440	0·340
Potash, in combination with silica	0·156	0·105
Soda, principally in combination with silica, and a little as common salt	0·066	0·060
Phosphoric acid	0·098	0·190
Sulphuric acid in combination with lime	0·111	0·012
Chlorine (in common salt)	0·012	0·012
Humus, with traces of azotised matter	4·100	0·184
	100·000	100·000

An inspection of the above analysis will show that the soil contains a very small proportion of salts of sulphuric acid—a circumstance which accounts for the favourable action of gypsum upon it.

2. The surface-soil (A) is a fine-grained loamy soil from Gandersheim, distinguished for the remarkably large crops of beans, peas, tares, &c., which it produces when manured with gypsum. (B) is the analysis of the subsoil. 100 parts contain :—

	(A)	(B)
Silica, with fine siliceous sand	90·221	92·324
Alumina	2·106	2·262
Peroxide and protoxide of iron	3·951	2·914
Peroxide of manganese	0·960	2·960
Lime, principally combined with phosphoric acid and humus	0·539	0·532
Magnesia, with silicate of potash, &c.	0·730	0·340
Potash	0·066	0·304
Soda	0·010	a trace
Phosphoric acid	0·367	0·122

	(A)	(B)
Sulphuric acid (in gypsum) . . .	a trace	0·010
Chlorine (in common salt) . . .	0·100	0·004
Humus and azotised matter . . .	0·900	——
Loss	0·140	0·228
	100·000	100·000

The analysis of this soil shows, that, with the exception of gypsum, every ingredient is present which is requisite for the nourishment of leguminous plants.— Hence it is that gypsum exerts such a favourable influence upon it.

3. Surface-soil (A) a strong loamy sand from Brunswick.   (B) the analysis of the subsoil.   100 parts contain :—

	(A)	(B)
Silica, with coarse siliceous sand . .	95·698	96·880
Alumina	0·504	0·890
Peroxide and protoxide of iron . .	2·496	1·496
Peroxide of manganese . . .	a trace	a trace
Lime	0·038	0·019
Magnesia	0·147	0·260
Potash and soda, the greatest part in		
combination with silica	0.090	0·079
Phosphate of iron	0·164	0·110
Sulphuric acid (in gypsum) . . .	0·007	a trace
Chlorine (in common salt) . : .	0·010	a trace
Humus	0·846	0·226
	100·000	100·000

This soil was much improved by manuring with lime and ashes.   It was then found well fitted for clover, beans, and peas.

4. Surface-soil (A) a loamy sand, from the environs of Brunswick.   (B) analysis of the subsoil at the depth of 8 feet.   100 parts contain :—

	(A)	(B)
Silica and fine siliceous sand . .	94·724	97·340
Alumina	1·638	0·806

	(A)	(B)
Protoxide and peroxide of iron with manganese	1·960	1·201
Lime	1·028	0·296
Magnesia	a trace	0·095
Potash and soda	0 077	0·112
Phosphoric acid	0·024	0015
Gypsum	0·010	a trace
Chlorine of the salt	0·207	a trace
Humus	0·512	0·135
	100·000	100·000

This soil produces luxuriant crops of lucern and sainfoin, as well as of all other plants the roots of which penetrate deeply into the ground. The reason is apparent The subsoil contains magnesia, which is wanting in the surface-soil.

5. Surface-soil (A) a loamy sand, from the environs of Brunswick. (B) analysis ot the subsoil at a depth of 2 feet. 100 parts contain :—

	(A)	(B)
Silica, with coarse siliceous sand	95.843	95·180
Alumina	0·600	1·600
Protoxide and peroxide of iron	1·800	2·200
Peroxide of manganese	a trace	a trace
Lime, in combination with silica	0·038	0·455
Magnesia in do. do	0·006	0·160
Potash and soda	0·005	0·004
Phosphate of iron	0·198	0·400
Sulphuric acid	0·002	a trace
Chlorine	0·006	0·001
Humus soluble in alkalies	1·000	. . .
Humus insoluble in alkalies	0·502	. . .
	100·000	100.000

This soil is characterised by its great sterility. White clover could not be made to grow upon it. The obvious cause of its poverty is a deficiency of lime, magnesia, potash, and gypsum; for we find that the fertility of the soil was much increased by manuring it with marl. The

white clover, which formerly had refused to grow on this soil, now grew upon it with much luxuriance. The aridity of the soil could not have been the cause of its sterility, for the stiff nature of the subsoil on which it rested prevented a deficiency of moisture.

6. Surface-soil (A) a loamy land, from the environs of Brunswick. (B) the analysis of the subsoil, at a depth of 2 feet. 100 parts contain:—

	(A)	(B)
Silica, with fine siliceous sand	94·998	96·490
Alumina	0·610	1·083
Protoxide and peroxide	1·080	1·472
Peroxide of manganese	0·268	0·400
Lime, in combination with silica	0·141	0·182
Magnesia, *idem*	0·208	0·205
Potash, *idem*	0·050	0·070
Soda, *idem*	0·044	0·050
Phosphate of iron	0·086	0·030
Gypsum	0·041	0·005
Common salt	0·004	0·003
Humus soluble in alkalies	0·400	0·010
Humus accompanied by azotised matter	2·070	. . .
Resinous matter	a trace	. . .
	100·000	100·000

This soil is by no means remarkable for itss terility, but is decidedly improved by manuring with burned ferruginous loam. It is, however, rendered still better by the use of burned marl—a manure which is rich in iron, potash, gypsum, and phosphate of lime. The marl does not exert so favourable an action when applied in its natural state; but the heat liberates the potash from the insoluble compound which it forms with silica.

7. Surface-soil (A) a loamy sand, from Brunswick, (B) analysis of the subsoil, at a depth of 1¼ feet. 100 parts contain:—

	(A)	(B)
Silica, with fine siliceous sand . .	92·980	96·414
Alumina	0·820	1·000
Protoxide and peroxide of iron . .	1·666	1·370
Peroxide of manganese . . .	0·188	0·240
Lime, combined with silica . . .	0·748	0·364
Magnesia, *idem*	0·168	0·160
Potash, *idem*	0·065	0·045
Soda, *idem*	0·130	0·082
Phosphate of iron	0·246	0·043
Sulphuric acid contained in gypsum . a trace	0·005	
Chlorine . . . . . . a trace	0·007	
Humus soluble in alkalies . . .	0·764	0·270
Humus, with azotised organic remains .	2·225	. . .
	100·000	100·000

This soil when manured with gypsum is very favour-
able to the production of leguminous plants and red
clover. But it is very remarkable, on account of the
rust which always attacks the corn plants which may be
grown upon it. This rust and mildew (*uredo linearis,
puccinia graminis*) is a disease which attacks the stem
and leaves, and is quite different from the *brand* (*uredo
glumarum*) which appears on the seeds and organs of
reproduction. Rust is most frequently detected on plants
growing on soils which contain bog-ore, or turf iron-ore.
According to Sprengel, rust contains phosphate of iron,
to which this chemist ascribes the origin of the disease.
It is very possible that other causes may operate in the
production of similar diseases.

8. Soil, a fine-grained loamy marl, from the vicinity
of Schoningen. It produces corn, which is, however,
very liable to blight. 100 parts contain:—

Silica, with siliceous sand	93·870
Alumina	1·248
Protoxide and peroxide of iron . .	1·418
Peroxide of manganese	0·360

Lime (principally carbonate)	0·546
Magnesia, *idem*	0·560
Potash, with silica	0·050
Soda, with silica	0·040
Phosphate of iron	0·246
Sulphuric acid with lime	0·027
Carbonic acid, with lime and magnesia	1·145
Humus soluble in alkalies	0·400
Humus	0·090
	100·000

It will be observed that a considerable quantity of phosphate of iron is contained, in this soil, and the corn which grows upon it is, as in the former case, disposed to rust.

9. Surface-soil (A) a loamy soil, from Brunswick, remarkable on account of producing buck-wheat, which is exceedingly poor in the grain. (B) analysis of the subsoil at a depth of $1\frac{1}{2}$ foot. 100 parts contain:—

	(A)	(B)
Silica, with coarse siliceous sand	95·114	92·458
Alumina	1·080	2·530
Protoxide and peroxide of iron	1·900	2·502
Protoxide and peroxide of manganese	0·320	0·920
Lime, in combination with silica	0·380	0·710
Magnesia, *idem*	0·300	0·551
Potash, with silica	0·020	0·120
Soda	0·004	0·034
Phosphate of iron	0·052	0·175
Sulphuric acid with lime	0·006	a trace
Chlorine (in common salt)	0·005	a trace
Humus soluble in alkalies	0·619	. . .
Humus	0·200	. . .
	100·000	100·000

By manuring the land with wood ashes, the soil is enabled to produce buck-wheat, with rich grain; the leguminous plants also thrive luxuriantly upon it. This increased fertility is due to the ashes, by means of which both potash and phosphates are supplied to the land.

10. Subsoil of a loamy, sandy soil, from Brunswick. It is remarkable for having produced excellent crops of hops for a long series of years. 100 parts, by weight, consist of:—

Silica, with siliceous sand	. 95·660
Alumina	. 1·586
Protoxide and peroxide of iron . .	. 1·616
Peroxide of manganese . . .	. 0·240
Lime, in combination with silica . .	. 0.083
Magnesia	. 0.080
Potash	. 0·030
Soda	. 0·220
Phosphoric acid	. 0·039
Sulphuric acid . . · . .	. 0·003
Chlorine	. a trace
Humus soluble in alkalies . . .	. 0·080
Humus	. 0·360
	100·000

Although the hops contain a large quantity of potash, soda, phosphoric acid, sulphuric acid, lime, and magnesia, yet we do not find that these exist in the soil in superabundant quantity. Nor is it necessary that they should, for the roots of the hops penetrate 8 or 10 feet deep into the soil, and search out the materials fitted to nourish the plants. Hence it is that hops thrive well on soils comparatively poor in their proper ingredients. The same is the case with all plants of a similar nature, the roots of which possess a tendency to extend in search of food; we see this particularly in lucern and sainfoin.

SOILS OF HEATHS.

11. Soil of a heath converted into arable land, in the vicinity of Brunswick. It is naturally sterile, but produces good crops when manured with lime, marl,

cow-dung, or the ashes of the heaths which grow upon it.

Silica and coarse siliceous sand . .	71·504
Alumina	0·780
Protoxide and peroxide of iron, principally combined with humus	0·420
Peroxide of manganese, *idem* . . .	0·220
Lime, *idem*	0·134
Magnesia, *idem*	0·032
Potash and soda, principally as silicates . .	0.058
Phosphoric acid, (principally as phosphate of iron)	0·115
Sulphuric acid (in gypsum) . . .	0·018
Chlorine (in common salt) . . .	0·014
Humus soluble in alkalies . . .	9·820
Humus, with vegetable remains . .	14·975
Resinous matters	1·910
	100·000

Ashes of the soil of the heath, before being converted into arable land :—

Silica, with siliceous sand . . .	92·641
Alumina	1·352
Oxides of iron and manganese . .	2·324
Lime, in combination with sulphuric and phosphoric acids . . .	0·929
Magnesia, combined with sulphuric acid .	0·283
Potash and soda (principally as sulphates and phosphates)	0·564
Phosphoric acid, combined with lime . .	0·250
Sulphuric acid, with potash, soda, and lime .	1·620
Chlorine in common salt . . .	0·037
	100·000

12. Surface-soil of a fine-grained loam, from the vicinity of Brunswick. It is remarkable from the circumstance, that not a single year passes in which corn plants are cultivated upon it without the stem of the plants being attacked by rust. Even the grain is covered with a yellow rust, and is much shrunk. 100 parts of the soil contain:—

Silica and fine siliceous sand . .	87·859
Alumina	2·652
Peroxide of iron with a large proportion of protoxide	5·132
Protoxide and peroxide of manganese . .	0·840
Lime principally combined with silica . . .	1·459
Magnesia, *idem*	0·280
Potash and soda, *idem*	0·090
Phosphoric acid in combination with iron . .	0·505
Sulphuric acid in combination with lime . .	0·068
Chlorine in common salt	0·006
Humus	1·109
	100·000

This soil does not suffer from want of drainage : it is
well exposed to the sun, is in an elevated situation, and
in a good state of cultivation.   In order to ascertain
whether the rust was due to the constituents of the soil,
(phosphate of iron?) or to certain fortuitous circumstances
unconnected with their operation, a portion of the land
was removed *to* another locality, and made *into an* artifi-
cial soil of fifteen inches in depth.   Upon this barley and
wheat were sown; but it was found, as in the former
case, that the plants were attacked by rust, whilst barley
growing on the land surrounding this soil was not at all
affected by the disease.   From this experiment it follows,
that certain constituents in the soil favour the develop-
ment of rust.

13. Soil of a heath which had been brought into cul-
tivation in the vicinity of Brunswick.   The analysis was
made before any kind of crops had been grown upon it.
Corn-plants were first reared upon the new soil, but were
found to be attacked by rust, even on those parts which
had been manured respectively with lime, marl, potash,
wood ashes, bone-dust, ashes of the heath plant, common
salt, and ammonia.   100 parts contain :—

Silica with coarse siliceous sand . . .	51·337
Alumina	0·528
Protoxide and peroxide of iron in combination	
with phosphoric and humic acids . .	0·398
Protoxide and peroxide of manganese . . .	0·005
Lime in combination with humus . .	0·230
Magnesia, *idem*	0·040
Potash and soda	0·010
Phosphoric acid	0·066
Sulphuric acid	0·022
Chlorine	0·014
Humus soluble in alkalies . . .	13·210
Resinous matters	2·040
Coal of humus and water . . .	32·100
	100·000

The next analysis represents the soil after being burnt.
100 parts by weight of the soil left after ignition only 50
parts.   100 parts of these ashes consisted of :—

Silica and siliceous sand . . .	95·204
Alumina	1·640
Peroxide of iron	1·344
Peroxide of manganese	0·080
Lime in combination with sulphuric acid .	0·544
Magnesia combined with silica . . .	0·465
Potash and soda	0·052
Phosphoric acid (principally as phosphate of iron)	0·330
Sulphuric acid	0·322
Chlorine	0·019
	100·000

By comparing this analysis with the one which has
preceded it, an increase in certain of the constituents is
observed, particularly with respect to the sulphuric acid,
potash, soda, magnesia, oxide of iron, oxide of manga-
nese, and alumina.   From this it follows, that the humus,
or in other words, the vegetable remains, must have con-
tained a quantity of these substances confined within it,
in such a manner that they were not exhibited by analysis.

Oats and barley were sown on this land the second year after being reclaimed, and both suffered much from rust, although different parts of the soil were manured with marl, lime, and peat-ashes; whilst other portions were left without manure. In the first year, all the different parts of the field produced potatoes, but they succeeded best in those divisions which had been manured with peat-ashes, lime, and marl. In the second year, oats mixed with a little barley were sown upon the soil; and the straw was found to be strongest on the parts treated with peat-ashes, lime, marl, and ashes of wood. Red clover was sown on the third year; it appeared in best condition on those portions of the soil manured with marl and lime. Upon the divisions of the field which had been left without manure, as well as on those manured with bone-dust, potash, ammonia, and common salt, the clover scarcely appeared above ground. The divisions of the field, which had been manured in the first year with peat-ashes, ammonia, and ashes of wood, were sown with buck-wheat after the removal of the first crop of clover. The buck-wheat succeeded very well on all the divisions, yet a marked difference was perceptible in favour of the portion treated with ammonia. These experiments show us, that a dressing of lime did not completely remove from the soil its tendency to impart rust to the plants grown upon it. Nevertheless it is highly probable, that as soon as the protoxide of iron became converted into the peroxide by exposure to the atmosphere, lime would possess more power in decomposing the phosphate of iron.

14. Subsoil of a loamy soil in the vicinity of Brunswick. It is remarkable from the circumstance that sainfoin cannot be cultivated upon it more than two or three

years in succession. The portion analysed was taken
from a depth of five feet. 100 parts contained:—

Silica with very fine siliceous sand	90·035
Alumina	1·976
Peroxide of iron	4·700
Protoxide of iron	1·115
Protoxide and peroxide of manganese	0·240
Lime	0.022
Magnesia	0·115
Potash and soda	0·300
Phosphoric acid, combined with iron	0·098
Sulphuric acid (the greatest part in combination with protoxide of iron)	1·399
Chlorine	a trace
	100·000

Now the results of the analysis give a sufficient account
of the failure of the sainfoin. The soil contains above one
per cent. of sulphate of the protoxide of iron (*green vitriol
of commerce*), a salt which exerts a poisonous action upon
plants. Lime is not present in quantity sufficient to
decompose this salt. Hence it is that sainfoin will not
thrive on this soil, nor indeed lucern, or any other of the
plants with deep roots. The evil cannot be obviated by
any methods sufficiently economical for the farmer,
because the soil cannot be mixed with lime at a depth of
five or six feet. For many years experiments have been
made in vain, in order to adapt this soil for sainfoin and
lucern, and much expense incurred, which could all have
been saved, had the soil been previously analysed. This
example affords a most convincing proof of the import-
ance of chemical knowledge to an agriculturist.

15. Surface soil (A) of a sandy loam in the vicinity of
Brunswick, celebrated for its beautiful crops of clover,
rye, potatoes, and barley. The clover must, however

always be manured with gypsum.   (B) is an analysis of
the subsoil at the depth of 1½ foot.   100 parts contain :—

	(A)	(B)
Silica with coarse siliceous sand .	94·274	95·146
Alumina	1·560	1·416
Peroxide of iron with a little phosphoric acid	2·496	2·528
Peroxide of manganese . . .	0·240	0·320
Lime	0·400	0·297
Magnesia	0·230	0·221
Potash and soda . . .	0·102	0·060
Sulphuric acid . . .	0·039	0·012
Chlorine	0·005	a trace
Humus soluble in alkaline carbonates	0·444	. . .
Humus	0·210	. . .
	100·000	100·000

The best property of this soil is, that its inferior layers
are nearly of the same composition as the superior, as far
as the inorganic constituents are concerned.   It is a soil
upon which the plants mentioned above will seldom fail ;
and as it possesses a very good mixture to the depth of
four or five feet, it would, doubtless, produce lucern also.

16. Surface-soil (A) of a sandy loam in the vicinity of
Brunswick.   It produces excellent crops of oats and
clover, when the latter is manured with gypsum.   (B)
Analysis of the subsoil taken from a depth of 1¼ foot.
100 parts contain :—

	(A)	(B)
Silica and siliceous sand . .	94·430	89·660
Alumina	1·474	0·980
Peroxide of iron with a little phosphoric acid	2·370	7·616
Peroxide of manganese . .	a trace	a trace
Lime, principally combined with silica	0·680	0·954
Magnesia, *idem* . . .	0·290	0·520
Potash	0·190 ⎫	0·150
Soda	0·010 ⎭	
Sulphuric acid . . .	a trace	a trace
Chlorine	0·015	a trace
Humus	0·541	0·120
	100·000	100·000

Both the surface and the subsoil contain only traces of sulphuric acid.   Hence the application of gypsum is attended with great benefit.   Without doubt, marl and lime would be found of essential service.

17. Soil from the environs of Brunswick, consisting principally of sand, and eminently remarked for its sterility.   It was, however, much improved by manuring it with marl which contained 24 per cent. of lime, together with magnesia, manganese, potash, soda, gypsum, and common salt.   100 parts of the soil contained : —

Silica and siliceous sand	95·841
Alumina	0·600
Protoxide and peroxide of iron	1·800
Peroxide of manganese	a trace
Lime in combination with silica	0·038
Magnesia, *idem*	0·006
Potash	0·002
Soda	0·003
Phosphoric acid combined with iron	0·198
Sulphuric acid	0·002
Chlorine	0·006
Humus	1·504
	100·000

Here another proof is presented, that a soil may be very rich in humus, and yet be very poor as regards fertility. By means of the marl, the inorganic ingredients of the plants are furnished to the soil, which contains them in very small quantity.

18. The soil of a very fertile loam from the vicinity of Walkenried.   100 parts contain :—

Silica with coarse-grained siliceous sand	88·456
Alumina	0·650
Peroxide and protoxide of iron, accompanied by much magnetic iron sand	5·608
Peroxide of manganese	0·560
Carbonate of lime	1·063
Carbonate of magnesia	1·688
Potash combined with silica	0·040

Soda combined with silica	0·012
Phosphate of lime	0·035
Sulphate of lime	a trace
Common salt	0·005
Humus soluble in alkalies	0·550
Humus, with several azotised organic remains .	1·333
	100·000

Gypsum acts most excellently upon this land. The soils in the southern range of the Harz mountains are particularly remarked for containing more magnesia than lime. Even the different varieties of marl contain a considerable quantity of magnesia. Thus in a specimen of marl obtained from the vicinity of Walkenried, I obtained 55½ per cent. carbonate of lime, and 30½ per cent. carbonate of magnesia; in another 41 per cent. lime, and 11 per cent. magnesia; and in a third, 47½ per cent. lime, and 13½ per cent. magnesia. Most of these soils contain also ½—1 per cent. of gypsum, and ½—1 per cent. phosphate of lime, and are, therefore, well fitted for manuring other lands.

19. Subsoil of a loam from a depth of 1½ foot. It occurs in the vicinity of Brunswick. The surface-soil is remarkable on account of producing beautiful red clover, on being manured with gypsum; although the soil itself contains only traces of lime, magnesia, potash, and phosphoric acid. 100 parts of the subsoil contained:—

Silica and coarse siliceous sand	88·980
Alumina	2·240
Protoxide and peroxide of iron	3·840
Peroxide of manganese	a trace
Carbonate of lime	2·720
Carbonate of magnesia	0·600
Potash and soda	0·095
Phosphate of lime	1·510
Sulphate of lime	a trace
Common salt	0·015
	100·000

Silica, with siliceous sand . . . . . 96·352
Alumina . . . . 1·859
Peroxide and protoxide of iron, with a little phos-
    phoric acid . . . . 1·120
Peroxide of manganese . . . . 0·160
Lime . . . . 0·112
Magnesia . . . . 0·141
Potash . . . . 0·093
Soda . . . . 0·007
Sulphuric acid . . . . 0·152
Chlorine . . . . 0·004
                               ——————
                               100·000

The ashes, on exposure to the air, absorbed ammonia.

23. Analysis of a very fertile loamy soil from Gottin-
gen. It is very rich in humus, and produces beautiful
crops of peas, beans, lucern, and beet. The sieve sepa-
rates from 100 parts of the soil :—

Small stones, principally limestone 1
Quarzy sand, with a little magnetic iron sand . . 15
Earthy part 84
                                ——
                                100

100 parts of the soil, freed from stones, consists of :—

Silica, and fine siliceous sand . . . . 83·298
Alumina, combined with silica . . . . 1·413
Alumina, partly in combination with humus . . 3·715
Peroxide and protoxide of iron, in combination
    with silica . . . . 0·724
Peroxide and protoxide of iron, partly free and
    partly in combination with humus . . . 2·244
Peroxide and protoxide of manganese . . 0·280
Lime, with coal of humus, sulphur, and phosphoric
    acid . . . . 1·814
Magnesia, combined with silica . . . . 0·422
Magnesia, combined with humus . . . .. 0·400
Potash . . . . 0·003
Soda . . . . 0·001
Phosphoric acid . . . . 0·166
Sulphuric acid . . . . 0·069
Chlorine . . . . 0·002
Carbonic acid (as carbonate of lime) . . . 0·440

Humus, soluble in alkalies	0·789
Humus, with a little water	3·250
Nitrogenous matter	0·960
Resinous matter	a trace
	100·000

The subsoil is of the same composition as the surface, with this difference only, that it contains more potash, soda, and chlorine*, and is interspersed with fragments of fresh-water shells. Hence it is that the soil produces the deep-rooted plants in such luxuriance.

24. Soil of a sterile moor, which had been burned three times, and upon which buck-wheat had been cultivated. 100 parts contained:—

Humus, soluble in alkalies	9·250
Vegetable remains, charcoal, quarzy sand, and earthy particles	90·750
	100·000

100 parts by weight left, after ignition, 10 parts of ashes. 100 parts of these ashes consisted of:—

Silica and siliceous sand	79·600
Alumina	6·288
Peroxide of iron	0·857
Peroxide of manganese	0·400
Carbonate of lime	7·652
Carbonate of magnesia	1·640
Potash	0·080
Soda	0·028
Phosphoric acid	0·215
Sulphate of lime (gypsum)	3·285
Chlorine	0·005
	100·000

Soils such as this, after having been burned several

---

* The portion of the surface-soil subjected to analysis was taken from the field after long-continued rain. Hence the small quantity of salts of potash and soda.

times, and made to produce buck-wheat, are completely deprived of their potash and soda; and in consequence of this are rendered quite barren. Hence it is that ashes of wood exert such an astonishing effect upon them.

25. Analysis of a very fertile loamy sand, from Osnabrück, near Rotherfeld. It is remarkable for being manured only once every 10 or 12 years, and bears beautiful wheat as the last crop. 100 parts contain :—

Silica, with coarse siliceous sand . . .	86·200
Alumina	2·000
Peroxide and protoxide of iron, with a little phosphoric acid	2·900
Peroxide of manganese	0·100
Carbonic acid, and a little phosphate of lime .	4·160
Carbonate of magnesia	0·520
Potash and soda	0·035
Phosphoric acid	0·020
Sulphuric acid	0·021
Chlorine	0·010
Humus, soluble in alkaline carbonates . . .	0·544
Humus	3·370
Nitrogenous matter	0·120
	100·000

The soil in question lies on the southern exposure of a hill, which consists of layers of limestone and marl. The rain-water penetrates through these layers, and becomes saturated with the soluble salts contained in them, such as potash, gypsum, common salt, lime, magnesia, and saltpetre. It afterwards reaches the soil, and manures it with these ingredients. It is only in this manner that we are enabled to explain the fertility of this soil; for, reasoning from its chemical composition, we would be induced, à priori, to suppose that it would be barren. At the base of this hill, certain portions of the land are covered with calcareous tuff, containing the above salts: a fact which proves that the water which penetrates

through the soil must also contain them in solution. The large proportion of humus exhibited by the analysis depends upon the nature of the manure to which it was treated.

26. Analysis of a heavy alluvial soil, from Norden. 100 parts contain :—

Silica, and very fine siliceous sand	81·513
Alumina	3·458
Peroxide of iron	3·488
Peroxide of manganese	0·560
Lime	0·319
Magnesia	0·740
Potash	a trace
Soda, in combination with silica	6·004
Phosphoric acid, in combination with lime	0·260
Sulphuric acid	0·008
Chlorine	0·008
Humus, soluble in alkalies	0·416
Humus and nitrogenous matter	0·196
	100·000

The portion of the soil subjected to analysis was taken at a depth of 10 inches, from a field which had received no manure for several years. It had previously produced in succession barley, beans, wheat, and grass, the latter for two years. The soil is remarkable, in a chemical point of view, from the large quantity of soda which it contains. Although the sulphuric acid, chlorine, and potash, are present in small quantity, yet this does not present any barrier to the development of the plants, as the surface-soil is 18 inches in depth.

27. Analysis of a heavy alluvial soil in the vicinity of. Norden.   100 parts contain:—

Silica, and very fine siliceous sand	7·9174
Alumina	3·016
Peroxide of iron	4·960
Peroxide of manganese	0·600
Carbonate of lime	2·171

Carbonate of magnesia	2·226
Potash, in combination with silica . . .	0·025
Soda, *idem*	6·349
Phosphoric acid	0·534
Sulphuric acid	a trace
Chlorine	0·005
Humus, soluble in alkalies	0·782
Humus, with nitrogenous matter	0·158
	100 000

The specimen for analysis was taken at a depth of
10 inches from the surface of a field, which had been
manured five years previously, and had produced since that
time rape, rye, wheat, and beans. The crops of all these
were plentiful, and of excellent quality. It is singular
that this soil, which contains such a small proportion of
gypsum, should be adapted for the cultivation of beans,
and must be ascribed to the depth of the surface-soil.
Yet, notwithstanding this, gypsum would form a bene-
ficial manure to the land.

28. Analysis of a very fertile alluvial soil, from Honig-
polder; no manure had ever been applied to it. 100
parts contain :—

Siliceous sand separated by the sieve . . .	4·5
Earthy portion of the soil	95·5
	100·0

100 parts of the latter consisted of :—

Silica, and fine siliceous sand	64·800
Alumina	5·700
Peroxide of iron	6·100
Peroxide of manganese	0·090
Lime	5·880
Magnesia	0·840
Potash, principally in combination with silica . .	0·210
Soda, *idem*	0 393
Phosphoric acid, combined with lime . . .	0·430
Sulphuric acid, *idem*	0·210
Chlorine (in common salt)	0·201

Carbonic acid, combined with lime . . .	3·920
Humus soluble in alkalies	2·540
Humus	5·600
Nitrogenous matter	1·582
Water	1·504
	100·000

Corn has been cultivated for seventy years upon this soil, which has never received dung or any other kind of manure; it is, however, occasionally fallowed. The subsoil retains the same composition as the surface-soil for a depth of 6—12 feet, so that it may be considered inexhaustible. When one portion of the soil is rendered unfitted for use, the inferior layers are brought up to the surface.

29. Analysis of a soil from Rahdingen, near Balje. In this case the sea has assisted in the formation of the soil. The field yielded beautiful corn after being manured with stable dung, being particularly remarked for its fine crops of wheat, beans, and winter barley. 100 parts contain:—

Silica, siliceous sand, and silicates . . .	87·012
Alumina	4·941
Peroxide of iron	2·430
Peroxide of manganese	0·192
Lime	0·292
Magnesia	0·145
Potash and soda soluble in water . . .	0·005
Phosphoric acid	0·114
Sulphuric acid	0·074
Chlorine (in common salt)	0·003
Humus, soluble in alkaline carbonates . .	0·658
Humus	2·668
Nitrogenous matter	1·412
Water	0·042
	100·000

30. Soil of a field remarkable for producing large

crops of hemp and horse-radish.   100 parts consisted
of:—

Silica and siliceous sand	84·021
Alumina	4·498
Peroxide of iron	5·120
Peroxide of manganese	2·080
Lime	0·942
Magnesia	1·740
Potash	0·050
Soda	0·012
Phosphoric acid	0·482
Sulphuric acid	0·012
Chlorine	0·008
Humus soluble in alkaline carbonates	0·897
Humus and nitrogenous matter	0·138

100·000

31. Surface-soil of a field near Drackenburg; it pro-
duces very bad red clover.   100 parts contain:—

Silica, with very fine siliceous sand	92·014
Alumina	2·652
Peroxide of iron	3·192
Peroxide of manganese	0·480
Lime	0·243
Magnesia	0·700
Potash combined with silica	0·125
Soda, *idem*	0·026
Phosphoric acid, in combination with lime	0·078
Sulphuric acid	a trace
Chlorine	a trace
Humus and nitrogenous matter	0·150
Humus soluble in alkaline carbonates	0·340

100·000

The cause that clover will not flourish on this soil is
probably due to the deficiency of gypsum and common
salt.

32. Surface-soil of a field near Paddingbuttel. This
field is particularly adapted for the growth of red clover.
100 parts consist of:—

Silica and siliceous sand . . . . . 93·720
Alumina . . . . 1·740
Peroxide of iron . . . . 2·060
Peroxide of manganese . . . . . . 0·320
Lime . . . . 0·121
Magnesia . . . . 0·700
Potash, principally in combination with silica . 0·062
Soda, *idem* . . . . 0·109
Phosphoric acid . . . . 0·103
Sulphuric acid . . . . 0·005
Chlorine (in common salt) . . . . . 0·050
Humus soluble in alkaline of carbonates . . 0·890
Humus with nitrogenous matter . . . . 0·120

100·000

SOILS IN BOHEMIA.

33. Surface-soil of a very fertile field in the province of Dobrawitz and Lautschin. 100 parts gave:—

Siliceous sand, with much magnetic iron sand . 4·286
Earthy part separated by the sieve . . . 95·714

100·000

An aqueous infusion of the soil contained gypsum, common salt, magnesia, and humus. 100 parts of the soil gave:—

Silica . . . . 89·175
Alumina . . . . 2·652
Protoxide and peroxide of iron . . . . 3·136
Peroxide of manganese . . . . . . 0·320
Lime . . . . 1·200
Magnesia . . . . 1·040
Potash, in combination with silica . . . 0·075
Soda, *idem* (principally) . . . . 0·354
Phosphoric acid, in combination with lime . . 0·377
Sulphuric acid, *idem* . . . . . . 0·081
Chlorine (in common salt) . . . . . 0·066

X 2

Humus soluble in alkalies	0·920
Humus	0·456
Nitrogenous matter	0·208
	100·000

34. Surface-soil of a very fertile field in the province of Dobrawitz and Lautschin. 100 parts of the earth consisted of :—

Siliceous sand, with a little magnetic iron sand	. 43·780
Finer part separated by the sieve . . .	. 56·220
	100·000

100 parts yielded to water 0·175 part of salts, consisting of common salt, gypsum, magnesia, and humic acid. 100 parts, by weight, of the earth consisted of :—

Silica	. 89·634
Alumina	. 3·224
Protoxide and peroxide of iron . . .	. 2·944
Peroxide of manganese	. 1·160
Lime	. 0·349
Magnesia	. 0·300
Potash, in combination with silica . .	. 0·160
Soda, *idem*	. 0·428
Phosphoric acid, in combination with lime .	. 0·246
Sulphuric acid, *idem*	. 0·005
Chlorine (in common salt)	. 0·012
Humus soluble in alkalies	. 0·750
Humus	. 0·340
Nitrogenous matter	. 0·448
	100·000

35. Analysis of a soil formed by the disintegration of basalt. 100 parts of the earth consisted of:—

Siliceous sand, with very much magnetic iron sand	8·428
Earthy portion of the soil	. 91·572
	100·000

The aqueous infusion of the earth contained only traces

of common salt and gypsum, with humus, lime, and magnesia.   100 parts consisted of:—

Silica	83·642
Alumina	3·978
Protoxide and peroxide of iron	5·312
Peroxide of manganese	0·960
Lime	1·976
Magnesia	0·650
Potash, in combination with silica . . .	0·080
Soda, idem	0·145
Phosphoric acid, in combination with lime . .	0·273
Sulphuric acid, idem	a trace
Humus soluble in alkaline carbonates . . .	1·270
Chlorine	a trace
Humus	0·234
Nitrogenous matter	1·480

100·00'

Manure consisting of gypsum, common salt, or ashes of wood, would be *highly conducive to the fertility* of this land.

SOILS IN THE "MARKGRAFSCHAFT MAHREN."

36. Surface-soil of a field very remarkable for its fertility. The field is called *Haargraben*, and is situated near the village of Nebstein. It has never been manured or allowed to lie fallow, and yet has produced for the last 160 years the most beautiful crops; thus furnishing a remarkable example of unimpaired fertility. 100·000 parts of this soil consisted of:—

Coarse and fine siliceous sand, with a little magnetic iron sand :	35·400
Earthy matter	64·600

100·000

100 parts of the earth yielded to water 0·010 sulphuric

acid, 0·010 chlorine, 0·007 soda, 0·012 magnesia, 0·010 potash, with a little silica, humus, and nitrogenous matter, but no appreciable trace of nitrates.   100 parts of the soil contained :—

Silica	77·209
Alumina	8·514
Peroxide of iron	6·592
Peroxide of manganese	1·520
Lime	0·927
Magnesia	1·160
Potash, principally in combination with silica	0·140
Soda, *idem*	0·640
Phosphoric acid, combined with lime and iron	0·651
Sulphuric acid, combined with lime . .	0·011
Chlorine (in common salt)	0·010
Humus soluble in alkalies	0·978
Humus	0·540
Nitrogenous matter	1·108
	100·000

It is apparent from the above analysis, that, notwithstanding the long period during which this land has been cultivated without manure, it still remains very rich in matters adapted for the nutrition of plants.

SOILS IN HUNGARY.

37. Analysis of a very fertile soil from Esákáng. 100 parts of the earth contained :—

Very fine siliceous sand	2·820
Earthy matter	97·180
	100·000

The aqueous decoction of the soil contained principally gypsum, common salt, silica, magnesia, and humus. 100 parts of the soil yielded :—

Silica	76·038
Alumina	4·654
Peroxide and protoxide of iron	6·112
Peroxide of manganese	0·900
Carbonate of lime	3·771
Carbonate of magnesia	4·066
Potash combined with silica	0·030
Soda combined with silica	1·379
Phosphoric acid, combined with lime	0·546
Sulphuric acid	0·021
Chlorine in common salt	0·015
Humus soluble in alkalies	1·160
Humus	1·100
Nitrogenous organic matter	0·208
	100·000

Subsoil of the same field at a depth of two feet. 100 parts consist of:—

Very fine siliceous sand with scales of mica	2·408
Earth separated by the sieve	97·592
	100·000

100 parts of the earth contain:—

Silica	59·581
Alumina	3·224
Peroxide and protoxide of iron	4·896
Peroxide of manganese	0·720
Carbonate of lime	17·953
Carbonate of magnesia	11·075
Potash combined with silica	0·150
Soda, principally combined with silica	0·891
Phosphoric acid combined with lime	0·846
Sulphuric acid, *idem*	0·004
Chlorine in common salt	0·004
Humus soluble in alkalies	0·536
Humus with nitrogenous organic matter	0·120
	100·000

BELGIUM.

88. Surface-soil of a field distinguished for its fertility.
It had received no manure for twelve years previous to
the time at which the analysis was executed. The rota-
tion of crops for the latter nine years was as follows :—
1. beans, 2. barley, 3. potatoes, 4. winter barley with red
clover, 5. clover, 6. winter barley, 7. wheat, 8. oats ; dur-
ing the ninth year it was allowed to lie fallow. The soil
is more clayey than loamy, and of a very fine grain.
Water extracted from the soil, 0·013 soda, 0·002 lime,
0·012 magnesia, 0·009 sulphuric acid, 0·003 potash,
0·003 chlorine, with traces of silica and humus. 100
parts contained :—

Silica	64·517
Alumina	4·810
Peroxide and protoxide of iron	8·316
Peroxide of manganese	0·800
Carbonate of lime	9·403
Carbonate of magnesia	10·361
Potash, principally combined with silica	0·100
Soda	0·013
Phosphoric acid	1·221
Sulphuric acid	0·009
Chlorine	0·003
Humus	0·447
	100·000

ENGLAND.

39. Surface-soil of a very fertile sandy field from the
vicinity of Tunbridge, Kent, according to Davy. 100
parts consisted of:—

Loose stones and gravel	13·250
Sand and silica	58·250
Alumina	3·250
Peroxide of iron	1·250

Carbonate of lime	4·750
Carbonate of magnesia	0·750
Common salt and extractive matter . . .	0·750
Gypsum	0·500
Matter destructible by heat	3·750
Vegetable fibre	3·500
Water	5·000
Loss	5·000
	100·000

The great Davy, who was convinced of the importance of the inorganic constituents of soils, has omitted to detect the phosphoric acid, potash, soda, and manganese. All these must have been present in the soil, for we are informed that it produced good hops, for which these ingredients are indispensable.

40. A good turnip soil from Holkham, Norfolk, yielded to Davy :—

Siliceous sand	88·888
Silica	1·666
Alumina	1·222
Peroxide of iron	0·334
Carbonate of lime	7·000
Vegetable and saline matter	0·556
Moisture	0·334
	100·000

In this case also, phosphoric acid, manganese, potash, magnesia, &c., have escaped detection by this acute chemist; yet doubtless they must be present in the soil, for we are informed that it produces good turnips.

41. An excellent wheat-soil from the neighbourhood of West Drayton, Middlesex, according to Davy. 100 parts contained :—

Sand and silica	72·800
Alumina	11·600
Carbonate of lime	11·200
Humus and moisture	4·400
	100·000

This analysis has been executed so imperfectly, that it only conveys a very feeble representation of the nature of the soil. A soil which bears good wheat must contain phosphate of potash, soda, chlorine, and sulphuric acid; yet none of these are exhibited by the analysis.

42. Surface-soil of a fertile field in the neighbourhood of Bristol. 100 parts contained : —

Silica and siliceous sand	60·000
Alumina	12·000
Peroxide of iron	3·500
Lime (carbonate)	7·500
Magnesia	0·500
Humus	1·250
Saline and extractive matter	0·750
Water	14·500
	100·000

Davy has made several analyses of various fertile soils, and since his time numerous other analyses have been published; but they are all so superficial, and in most cases so inaccurate, that we possess no means of ascertaining the composition or nature of English arable land.

SWEDEN.

43. Surface-soil of a field which produces the most abundant crops, and has never been manured. (Berzelius.) 100 parts consist of:—

Siliceous sand	57·900
Silica	14·500
Alumina	2·000
Phosphates of lime and iron	6·000
Carbonate of lime	11·100
Carbonate of magnesia	1·000
Insoluble extractive matter	1·250
Insoluble extractive matter destructible by heat	4·000
Animal matter	1·600
Resin	0·250
Loss	0·400
	100·000

ʊ   This great chemist has strangely omitted to detect in the soil potash, soda, chlorine, sulphuric acid, and manganese. As this soil is eminent for its fertility, there cannot be the slightest doubt that all these ingredients must have existed in it in notable quantity.

ISLAND OF JAVA.

44. A very fine-grained loamy soil, coloured yellow by peroxide of iron, consisted of: —

Silica and siliceous sand	67·660
Alumina	13·572
Peroxide and protoxide of iron	10·560
Peroxide of manganese	1·640
Lime	0·912
Magnesia	0·570
Potash, principally in combination with silica	0·030
Soda, *idem*	0·184
Phosphoric acid	0·391
Sulphuric acid	0·038
Chlorine	0·010
Humus	0·368
Water with carbonic acid	4·065
	100·000

WEST INDIES (PORTO RICO).

45. Surface-soil of a very barren field. 100 parts contained :—

Silica and siliceous sand	70·900
Alumina	6·996
Peroxide, and protoxide of iron (much magnetic iron sand)	6·102
Peroxide of manganese	0·200
Lime	2·218
Magnesia	3·280

Potash	0·130
Carbonate of soda	6·556
Phosphoric acid, combined with lime . . .	1·362
Sulphuric acid, combined with lime . . .	0.149
Chlorine in common salt	0·067
Humus soluble in alkalies	0·540
Humus	1·500
	100·000

This soil is improved by gypsum. Its sterility is due to the excessive quantity of carbonate of soda which is present.

NORTH AMERICA.

46. Surface-soil of alluvial land in Ohio, remarkable for its great fertility. 100 parts consisted of:—

Silica and fine siliceous sand	79·538
Alumina	7·306
Peroxide and protoxide of iron (much magnetic iron	
sand)	5·824
Peroxide of manganese	1·320
Lime	0·619
Magnesia	1·024
Potash, principally combined with silica . .	0·200
Soda	0·024
Phosphoric acid, combined with lime and oxide of	
iron	1·776
Sulphuric acid, combined with lime	0·122
Chlorine	0·036
Humus soluble in alkalies	1·950
Nitrogenous organic matter . .	0·236
Wax and resinous matter . . .	0·025
	100·000

47. (A.) Surface-soil of a mountainous district in the neighbourhood of Ohio. (B.) analysis of the subsoil. This soil is also distinguished for its great fertility. 100 parts contain :—

	(A)	(B)
Silica with fine siliceous sand	87·143	94·261
Alumina	5·666	1·376
Peroxide and protoxide of iron	2·220	2·336
Peroxide of manganese	0·360	1·200
Lime	0·564	0·243
Magnesia	0·312	0·310
Potash principally combined with silica	0·120 ⎫	
Soda	0·025 ⎭	0·240
Phosphoric acid	0·060	a trace
Sulphuric acid	0·027	0·034
Chlorine	0·036	a trace
Humus soluble in alkalies	1·304	
Humus	1·072	
Carbonic acid, combined with lime	0·080	
Nitrogenous organic matter	1·011	
	100·000	100·000

In the preceding part of the chapter we have inserted a number of analyses of various soils, as well as the conclusions deduced from them, by means of which the farmer may be enabled to ascertain the manures best adapted for each variety of soil. By inspecting the analyses of the sterile soils, it will be apparent that it is in the power of chemistry to point out the causes of their sterility. The general cause which conduces to the sterility of soils is either the absence of certain constituents indispensable for the growth of plants, or the presence of others which exert an injurious or poisonous action. The analyses are those of Dr. Sprengel,—a chemist who has unceasingly occupied himself for the last twenty years in endeavouring to point out the importance of the inorganic ingredients of a soil for the development of plants cultivated upon it. He considers as essential all the inorganic bodies found in the ashes of

plants. Now, although we cannot coincide with him in the opinion that iron and manganese are indispensable for vegetable life, (for these bodies are found as excrementitious matter only in the bark, and never form a constituent of an organ,) yet we gratefully acknowledge the valuable services which he has rendered to agriculture, by furnishing a natural explanation of the action of ashes, marl, &c., in the improvement of a soil. Sprengel has shown that these mineral manures afford to a soil alkalies, phosphates, and sulphates; and further, that they can exert a notable influence only on those soils in which they are absent or deficient. In a former chapter of this book I have endeavoured to point out the importance of considering these constituents as intimately connected with the vital processes of the vegetable organism, and have shown that the different families of plants contain unequal quantities of inorganic ingredients. This subject has been left unexamined by Sprengel, yet it is one of much importance; for the application of manures must be regulated by the composition of the plants which are cultivated on any particular soil. Still the composition of the soil must always be kept in view. Thus it would be perfect extravagance to manure certain soils with marl, ashes, or gypsum; whilst, on the contrary, these compounds would produce the most beneficial results on other lands.

In a former part of the work, the principal action of gypsum upon vegetation was ascribed to the decomposition and fixation of the carbonate of ammonia contained in rain-water; but gypsum exerts a two-fold action. The power of decomposing carbonate of ammonia, and of fixing the ammonia, is not peculiar to gypsum, but is shared also by other salts of lime (chloride of calcium,

for example). But it acts also as a *sulphate*, and when useful as such cannot be replaced by any other salt of lime which does not contain sulphuric acid.

Hence gypsum can be replaced as a manure only by a mixture of a salt of lime with ammonia, and a salt of sulphuric acid. Sulphate of ammonia can therefore be substituted for gypsum, and exerts a more rapid and effectual action. In France, sulphuric acid has been poured upon the fields after the removal of the crops, and has been found to form a good manure. But this is merely a process for forming gypsum *in situ;* for the soils upon which it is applied contain much lime, which enters into combination with the sulphuric acid. It would certainly be much more advantageous to form sulphate of ammonia by adding the acid to putrefied urine, and to apply this mixture to the field.

mixed with the soil instead of sand; the vegetation was always rendered stronger and more vigorous.

" At the same time that these experiments were performed with mixtures of charcoal with different soils, the charcoal was also used free from any addition, and in this case the best results were obtained. Cuts of plants from different genera took root in it well and quickly ; I mention here only the *Euphorbia fastuosa* and *fulgens* which took root in ten days, *Pandanus utilis* in three months, *P. amaryllifolius*, *Chamœdorea elatior* in four weeks, *Piper nigrum*, *Begonia*, *Ficus*, *Cecropia*, *Chiococca*, *Buddleya*, *Hakea*, *Phyllanthus*, *Capparis*, *Laurus*, *Stifftia*, *Jacquinia*, *Mimosa*, *Cactus*, in from eight to ten days, and several others amounting to forty species, including *Ilex*, and many others. Leaves, and pieces of leaves, and even *pedunculi*, or petioles, took root and in part budded in pure charcoal. Amongst others we may mention the *foliola* of several of the *Cycadeæ* as having taken root, as also did parts of the leaves of the *Begonia Telfairiæ*, and *Jacaranda brasiliensis ;* leaves of the *Euphorbia fastuosa*, *Oxalis Barrilieri*, *Ficus*, *Cyclamen*, *Polyanthes*, *Mesembryanthemum ;* also the delicate leaves of the *Lophospermum* and *Martynia*, pieces of a leaf of the *Agave americana ;* tufts of *Pinus*, &c. ; and all without the aid of a previously formed bud.

" Pure charcoal acts excellently as a means of curing unhealthy plants. A *Dorianthes excelsa,* for example, which had been drooping for three years, was rendered completely healthy in a very short time by this means. An orange-tree which had the very common disease in which the leaves become yellow, acquired within four weeks its healthy green colour, when the upper surface of the earth was removed from the pot in which it was contained, and a ring of charcoal of an inch in thickness strewed in its place around the periphery of the pot. The same was the case with the *Gardenia.*

" I should be led too far were I to state all the results of the experiments which I have made with charcoal. The

object of this paper is merely to show the general effect exercised by this substance on vegetation ; but the reader who takes particular interest in the subject will find more extensive observations in the ' *Allgemeine Deutsche Garten-zeitung*' of Otto and Dietrich, in Berlin ; or Loudon's *Gardener's Magazine* for March, 1841.

"The charcoal employed in these experiments was the dust-like powder of charcoal from firs and pines, such as is used in the forges of blacksmiths, and may be easily procured in any quantity. It was found to have most effect when allowed to lie during the winter exposed to the action of the air. In order to ascertain the effects of different kinds of charcoal, experiments were also made upon that obtained from the hard woods and peat, and also upon animal charcoal, although I foresaw the probability that none of them would answer so well as that of pinewood, both on account of its porosity and the ease with which it is decomposed *.

" It is superfluous to remark, that in treating plants in the manner here described, they must be plentifully supplied with water, since the air having such free access penetrates and dries the roots, so that unless this precaution is taken, the failure of all such experiments is unavoidable.

" The action of charcoal consists primarily in its preserving the parts of the plants with which it is in contact—whether they be roots, branches, leaves, or pieces of leaves—unchanged in their vital power for a long space of time, so that the plant obtains time to develop the organs which are necessary for its further support and propagation. There can scarcely be a doubt also that the charcoal undergoes decomposition ; for after being used five to six years it becomes a coaly earth ; and if this is the case, it must yield carbon, or

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* M. Lucas has recently repeated these experiments, and found that the animal charcoal obtained by the calcination of bones possesses a decided advantage over all other kinds of charcoal, which he subjected to experiment.—*Liebig's Annalen*, Band xxxix. *Heft* i. *S.* 127.

carbonic oxide, abundantly to the plants growing in it, and thus afford the principal substance necessary for the nutrition of vegetables[*]. In what other manner indeed can we explain the deep green colour and great luxuriance of the leaves and every part of the plants, which can be obtained in no other kind of soil, according to the opinion of men well qualified to judge ? It exercises likewise a favourable influence by decomposing and absorbing the matters excreted by the roots, so as to keep the soil free from the putrefying substances which are often the cause of the death of the *spongiolæ.* Its porosity, as well as the power which it possesses of absorbing water with rapidity, and, after its saturation, of allowing all other water to sink through it, are causes also of its favourable effects. These experiments show what a close affinity the component parts of charcoal have to all plants, for every experiment was crowned with success, although plants belonging to a great many different families were subjected to trial." (*Buchner's Repertorium,* ii. *Reihe,* xix. *Bd. S.* 38.)

ON A MODE OF MANURING VINES.

The observations contained in the following pages should be extensively known, because they furnish a remarkable proof of the principles which have been stated in the preceding part of the work, both as to the manner in which manure acts, and on the origin of the carbon and nitrogen of plants.

[*] As some misconception has arisen regarding this explanation of the action of charcoal upon vegetation, and an idea propagated that the introduction of these opinions into this work incorporated them with those of Liebig, it is necessary to state that they are merely inserted here as part of the papers of M. Lucas. The true explanation has been given in a former part of the work, viz., that charcoal possesses the power of absorbing carbonic acid and ammonia from the atmosphere, which serve for the nourishment of plants.—ED.

They prove that a vineyard may be retained in fertility without the application of animal matters, when the leaves and branches pruned from the vines are cut into small pieces and used as manure. According to the first of the following statements, both of which merit complete confidence, the perfect fruitfulness of a vineyard has been maintained in this manner for eight years, and according to the second statement for ten years.

Now, during this long period, no carbon was conveyed to the soil, for that contained in the pruned branches was the produce of the plant itself, so that the vines were placed exactly in the same condition as trees in a forest which receive no manure. Under ordinary circumstances a manure containing potash must be used, otherwise the fertility of the soil will decrease. This is done in all wine-countries, so that alkalies to a very considerable amount must be extracted from the soil.

When, however, the method of manuring now to be described is adopted, the quantity of alkalies exported in the wine does not exceed that which the progressive disintegration of the soil every year renders capable of being absorbed by the plants. On the Rhine one litre of wine is calculated as the yearly produce of a square metre of land (10·8 square feet English). Now if we suppose that the wine is three-fourths saturated with cream of tartar, a proportion much above the truth, then we remove from every square metre of land with the wine only 1·8 gramme of potash. 1000 grammes (1 litre) of champagne yield only 1·54, and the same quantity of Wachenheimer 1·72 of a residue which after being heated to redness is found to consist of carbonates.

One vine-stock, on an average, grows on every square metre of land, and 1000 parts of the pruned branches contain 56 to 60 parts of carbonate, or 38 to 40 parts of pure potash. Hence it is evident that 45 grammes, or 1 ounce, of these branches contain as much potash as 1000 grammes

(1 litre) of wine. But from ten to twenty times this quantity of branches are yearly taken from the above extent of surface.

In the vicinity of Johannisberg, Rudesheim, and Budesheim, new vines are not planted after the rooting out of the old stocks, until the land has lain for five or six years in barley and esparsette or lucern ; in the sixth year the young stocks are planted, but not manured till the ninth.

ON THE MANURING OF THE SOIL IN VINEYARDS.*

" In reference to an article in your paper, No. 7, 1838, and No. 29, 1839, I cannot omit the opportunity of again calling the public attention to the fact, that nothing more is necessary for the manure of a vineyard than the branches which are cut from the vines themselves.

" My vineyard has been manured in this way for eight years, without receiving any other kind of manure, and yet more beautiful and richly laden vines could scarcely be pointed out. I formerly followed the method usually practised in this district, and was obliged in consequence to purchase manure to a large amount. This is now entirely saved, and my land is in excellent condition.

" When I see the fatiguing labour used in the manuring of vineyards—horses and men toiling up the mountains with unnecessary materials, I feel inclined to say to all, Come to my vineyard and see how a bountiful Creator has provided that vines shall manure themselves, like the trees in a forest, and even better than they ! The foliage falls from trees in a forest, only when they are withered, and they lie for years before they decay ; but the branches are pruned from the vine in the end of July or beginning of August

* Slightly abridged from an article by M. Krebs of Seeheim in the " Zeitschrift für die landwirthschaftlichen Vereine des Großherzogthums Hessen." No. 28, July 9, 1840.

whilst still fresh and moist. If they are then cut into small
pieces and mixed with the earth, they undergo putrefaction
so completely, that, as I have learned by experience, at the
end of four weeks not the smallest trace of them can be
found."

" REMARKS OF THE EDITOR.—We find the following notices
of the same fact in Henderson's ' Geschichte der Weine der
alten und neuen Zeit :'—

" ' The best manure for vines is the branches pruned from
the vines themselves, cut into small pieces, and immediately
mixed with the soil.'

" These branches were used as manure long since in the
Bergstrasse. M. Frauenfelder says :*

" ' I remember that twenty years ago, a man called Peter
Müller had a vineyard here which he manured with the
branches pruned from the vines, and continued this practice
for thirty years. His way of applying them was to hoe them
into the soil, after having cut them into small pieces.

" ' His vineyard was always in a thriving condition ; so
much so, indeed, that the peasants here speak of it to this
day, wondering that old Müller had so good a vineyard, and
yet used no manure.'

" Lastly, Wilhelm Ruf of Schriesheim writes :

" ' For the last ten years I have been unable to place
dung on my vineyard, because I am poor and can buy none.
But I was very unwilling to allow my vines to decay, as
they are my only source of support in my old age ; and I
often walked very anxiously amongst them, without know-
ing what I should do. At last my necessities became
greater, which made me more attentive, so that I re-
marked that the grass was longer on some spots where
the branches of the vine fell than on those on which there

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* *Badisches landwirthschaftliches Wochenblatt*, v. 1834, 8. 52 and 79.

were none. So I thought upon the matter, and then said to myself: If these branches can make the grass large, strong, and green, they must also be able to make my plants grow better, and become strong and green. I dug therefore my vineyard as deep as if I would put dung into it, and cut the branches into pieces, placing them in the holes and covering them with earth. In a year I had the very great satisfaction to see my barren vineyard become quite beautiful. This plan I continued every year, and now my vines grow splendidly, and remain the whole summer green, even in the greatest heat.

" ' All my neighbours wonder very much how my vineyard is so rich, and that I obtain so many grapes from it, and yet they all know that I have put no dung upon it for ten years.' "

PART II.

CHAPTER I.

CHEMICAL TRANSFORMATIONS.

WOODY fibre, sugar, gum, and all such organic com-
pounds, suffer certain changes when in contact with other
bodies, that is, they suffer *decomposition.*

There are two distinct modes in which these decom-
positions take place in organic chemistry.

When a substance composed of two compound bodies,
crystallised oxalic acid for example, is brought in con-
tact with concentrated sulphuric acid, a complete decom-
position is effected upon the application of a gentle heat.
Now crystallised oxalic acid is a combination of water
with the anhydrous acid ; but concentrated sulphuric acid
possesses a much greater affinity for water than oxalic
acid, so that it attracts all the water of crystallization from
that substance. In consequence of this abstraction of the
water, anhydrous oxalic acid is set free ; but as this acid
cannot exist in a free state, a division of its constituents
necessarily ensues, by which carbonic acid and carbonic
oxide are produced, and evolved in the gaseous form in
equal volumes. In this example, the decomposition is the
consequence of the removal of two constituents (the ele-

ments of water), which unite with the sulphuric acid, and its cause is the superior affinity of the acting body (the sulphuric acid) for water. In consequence of the removal of the component parts of water, the remaining elements enter into a new form ; in place of oxalic acid, we have its elements in the form of carbonic acid and carbonic oxide.

This form of decomposition, in which the change is effected by the agency of a body which unites with one or more of the constituents of a compound, is quite analogous to the decomposition of inorganic substances. When we bring sulphuric acid and nitrate of potash together, nitric acid is separated in consequence of the affinity of sulphuric acid for potash; in consequence, therefore, of the formation of a new compound (sulphate of potash).

In the second form of these decompositions, the chemical affinity of the acting body causes the component parts of the body which is decomposed to combine, so as to form new compounds, of which either both, or only one, combine with the acting body. Let us take dry wood, for example, and moisten it with sulphuric acid; after a short time the wood is carbonised, while the sulphuric acid remains unchanged, with the exception of its being united with more water than it possessed before. Now this water did not exist as such in the wood, although its elements, oxygen and hydrogen, were present; but by the chemical attraction of sulphuric acid for water, they were in a certain measure compelled to unite in this form ; and in consequence of this, the carbon of wood was separated as charcoal.

Hydrocyanic acid, and *water,* in contact with hydrochloric acid, are mutually decomposed. The nitrogen of the hydrocyanic acid, and a certain quantity of the hydrogen of the water, unite together and form *ammonia :* whilst

the carbon and hydrogen of the hydrocyanic acid combine
with the oxygen of the water, and form *formic acid.* The
ammonia combines with the muriatic acid. Here the
contact of muriatic acid with water and hydrocyanic acid
causes a disturbance in the attraction of the elements of
both compounds, in consequence of which they arrange
themselves into new combinations, one of which—ammo-
nia—possesses the power of uniting with the acting body.

Inorganic chemistry can present instances analogous
to this class of decomposition also; but there are forms
of organic chemical decomposition of a very different
kind, in which none of the component parts of the matter
which suffers decomposition enter into combination with
the body which determines the decomposition. In cases
of this kind a disturbance is produced in the mutual
attraction of the elements of a compound, and they in
consequence arrange themselves into one or several new
combinations, which are incapable of suffering further
change under the same conditions.

When, by means of the chemical affinity of a second
body, by the influence of heat, or through any other
causes, the composition of an organic compound is made
to undergo such a change, that its elements form two or
more new compounds, this manner of decomposition is
called a chemical *transformation* or *metamorphosis.* It is
an essential character of chemical transformations, that
none of the elements of the body decomposed are singly
set at liberty.

The changes, which are designated by the terms *fer-
mentation, decay,* and *putrefaction,* are chemical transforma-
tions effected by an agency which has hitherto escaped
attention, but the existence of which will be proved in
the following pages.

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CHAPTER II.

ON THE CAUSES WHICH EFFECT FERMENTATION, DECAY,* AND PUTREFACTION.

ATTENTION has been recently directed to the fact, that a body in the act of combination or decomposition exercises an influence upon any other body with which it may be in contact. Platinum, for example, does not decompose nitric acid; it may be boiled with this acid without being oxidised by it, even when in a state of such fine division, that it no longer reflects light (black spongy platinum). But an alloy of silver and platinum dissolves with great ease in nitric acid; the oxidation which the silver suffers, causes the platinum to submit to the same change; or, in other words, the latter body, from its contact with the oxidizing silver, acquires the property of decomposing nitric acid.

Copper does not decompose water, even when boiled in dilute sulphuric acid; but an alloy of copper, zinc, and nickel dissolves easily in this acid, with evolution of hydrogen gas.

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* An essential distinction is drawn in the following part of the work, between *decay* and *putrefaction* (*Verwesung und Fäulniss*), and they are shown to depend on different causes ; but as the word *decay* is not generally applied to a distinct species of decomposition, and does not indicate its true nature, I shall in future, at the suggestion of the author, employ the term *eremacausis*, the meaning of which has been already explained.—ED.

Tin decomposes nitric acid with great facility, but water with difficulty; and yet, when tin is dissolved in nitric acid, hydrogen is evolved at the same time, from a decomposition of the water contained in the acid, and ammonia is formed in addition to oxide of tin.

In the examples here given, the only combination or decomposition which can be explained by chemical affinity is the last. In the other cases, electrical action ought to have retarded or prevented the oxidation of the platinum or copper while they were in contact with silver or zinc; but, as experience shows, the influence of the opposite electrical conditions is more than counter-balanced by chemical actions.

The same phenomena are seen in a less dubious form in compounds, the elements of which are held together only by a feeble affinity. It is well known that there are chemical compounds of so unstable a nature, that changes in temperature and electrical condition, or even simple mechanical friction, or contact with bodies of apparently totally indifferent natures, cause such a disturbance in the attraction of their constituents, that the latter enter into new forms, without any of them combining with the acting body. These compounds appear to stand but just within the limits of chemical combination, and agents exercise a powerful influence on them, which are completely devoid of action on compounds of a stronger affinity. Thus, by a slight increase of temperature, the elements of hypo-chlorous acid separate from one another with evolution of heat and light; chloride of nitrogen explodes by contact with many bodies, which combine neither with chlorine nor nitrogen at common temperatures; and the contact of any solid substance is sufficient to cause the explosion of iodide of nitrogen, or fulminating silver.

oxygen of part of the oxide escapes with the carbonic acid, and metallic silver remains in the state of a black powder. (Berzelius.)

Now no other explanation of these phenomena can be given, than that a body in the act of combination or decomposition enables another body, with which it is in contact, to enter into the same state. It is evident that the active state of the atoms of one body has an influence upon the atoms of a body in contact with it; and if these atoms are capable of the same change as the former, they likewise undergo that change; and combinations and decompositions are the consequence. But when the atoms of the second body are not capable of such an action, any further disposition to change ceases from the moment at which the atoms of the first body assume the state of rest, that is, when the changes or transformations of this body are quite completed.

This influence, exerted by one compound upon the other, is exactly similar to that which a body in the act of combustion exercises upon a combustible body in its vicinity; with this difference only, that the causes which determine the participation and duration of these conditions are different. For the cause, in the case of the combustible body, is heat, which is generated every moment anew; whilst in the phenomena of decomposition and combination, which we are considering at present, the cause is a body in the state of chemical action, which exerts the decomposing influence only so long as this action continues.

Numerous facts show that motion alone exercises a considerable influence on chemical forces. Thus, the power of cohesion does not act in many saline solutions, even when they are fully saturated with salts, if they are per-

mitted to cool whilst at rest. In such a case, the salt
dissolved in a liquid does not crystallise; but when a grain
of sand is thrown into the solution, or when it receives
the slightest movement, the whole liquid becomes sud-
denly solid while heat is evolved. The same phenomenon
happens with water, for this liquid may be cooled much
under 32° F. (0° C.), if kept completely undisturbed, but
solidifies in a moment when put in motion.

The atoms of a body must in fact be set in motion
before they can overcome the *vis inertiæ*, so as to arrange
themselves into certain forms. A dilute solution of a salt
of potash mixed with tartaric acid yields no precipitate
whilst at rest; but if motion is communicated to the solu-
tion by agitating it briskly, solid crystals of cream of tartar
are deposited. A solution of a salt of magnesia also, which
is not rendered turbid by the addition of phosphate of
ammonia, deposits the phosphate of magnesia and ammo-
nia on those parts of the vessel touched with the rod
employed in stirring.

In the processes of combination and decomposition
under consideration, motion, by overcoming the *vis iner-
tiæ*, gives rise immediately to another arrangement of the
atoms of a body, that is, to the production of a compound
which did not before exist in it. Of course these atoms
must previously possess the power of arranging themselves
in a certain order, otherwise both friction and motion
would be without the smallest influence.

The simple permanence in position of the atoms of a
body is the reason that so many compounds appear to
present themselves in conditions and with properties
different from those which they possess, when they obey
the natural attractions of their atoms. Thus, sugar and
glass, when melted and cooled rapidly, are transparent,

of a conchoidal fracture, and elastic and flexible to a
certain degree. But the former becomes dull and opaque
on keeping, and exhibits crystalline faces by cleavage,
which belong to crystallised sugar. Glass assumes also
the same condition, when kept soft by heat for a long
period; it becomes white, opaque, and so hard as to
strike fire with steel. Now, in both these bodies, the
compound molecules evidently have different positions in
the two forms. In the first form their attraction did not
act in the direction in which their power of cohesion was
strongest. It is known also, that when sulphur is melted
and cooled rapidly by throwing it into cold water, it
remains transparent, elastic, and so soft that it may be
drawn out into long threads; but that after a few hours
or days, it becomes again hard and crystalline.

The remarkable fact here is, that the amorphous sugar
or sulphur returns again into the crystalline condition,
without any assistance from an exterior cause; a fact
which shows that their molecules have assumed another
position, and that they possess, therefore, a certain degree
of mobility, even in the condition of a solid. A very rapid
transposition or transformation of this kind is seen in arra-
gonite, a mineral which possesses exactly the same compo-
sition as calcareous spar, but of which the hardness and
crystalline form prove that its molecules are arranged in
a different manner. When a crystal of arragonite is
heated, an interior motion of its molecules is caused by the
expansion; the permanence of their arrangement is
destroyed; and the crystal splinters with much violence,
and falls into a heap of small crystals of calcareous spar.

It is impossible for us to be deceived regarding the
causes of these changes. They are owing to a disturbance
of the state of the equilibrium, in consequence of which

the particles of the body put in motion obey other affinities or their own natural attractions.

But if it is true, as we have just shown it to be, that mechanical motion is sufficient to cause a change of condition in many bodies, it cannot be doubted that a body in the act of combination or decomposition is capable of imparting the same condition of motion or activity in which its atoms are to certain other bodies: or in other words, to enable other bodies with which it is in contact to enter into combinations, or suffer decompositions.

The reality of this influence has been already sufficiently proved by the facts derived from inorganic chemistry, but it is of much more frequent occurrence in the relations of organic matter, and causes very striking and wonderful phenomena.

By the terms *fermentation, putrefaction,* and *eremacausis,* are meant those changes in form and properties which compound organic substances undergo when separated from the organism, and exposed to the influence of water and a certain temperature. Fermentation and putrefaction are examples of that kind of decomposition, which we have named transformations: the elements of the bodies capable of undergoing these changes arrange themselves into new combinations, in which the constituents of water generally take a part.

Eremacausis (or decay) differs from fermentation and putrefaction, inasmuch as it cannot take place without the access of air, the oxygen of which is absorbed by the decaying bodies. Hence it is a process of slow combustion, in which heat is uniformly evolved, and occasionally even light. In the processes of decomposition termed fermentation and putrefaction, gaseous products are very

frequently formed, which are either inodorous, or possess a very offensive smell.

The transformations of those matters which evolve gaseous products without odour, are now, by pretty general consent, designated by the term *fermentation;* whilst to the spontaneous decomposition of bodies which emit gases of a disagreeable smell, the term *putrefaction* is applied. But the smell is of course no distinctive character of the nature of the decomposition, for both fermentation and putrefaction are processes of decomposition of a similar kind, the one of substances destitute of nitrogen, the other of substances which contain it.

It has also been customary to distinguish from fermentation and putrefaction a particular class of transformations, viz., those in which conversions and transpositions are effected without the evolution of gaseous products. But the conditions under which the products of the decomposition present themselves are purely accidental; there is therefore no reason for the distinction just mentioned.

CHAPTER III.

FERMENTATION AND PUTREFACTION.

SEVERAL bodies appear to enter spontaneously into the states of fermentation and putrefaction, particularly such as contain nitrogen or azotised substances. Now, it is very remarkable, that very small quantities of these substances, in a state of fermentation or putrefaction, possess the power of causing unlimited quantities of similar matters to pass into the same state. Thus, a small quantity of the juice of grapes in the act of fermentation, added to a large quantity of the same fluid which does not ferment, induces the state of fermentation in the whole mass. So likewise the most minute portion of milk, paste, juice of the beet-root, flesh, or blood, in the state of putrefaction, causes fresh milk, paste, juice of the beet-root, flesh, or blood, to pass into the same condition when in contact with them.

These changes evidently differ from the class of common decompositions which are effected by chemical affinity; they are chemical actions, conversions, or decompositions, excited by contact with bodies already in the same condition. In order to form a clear idea of these processes, analogous and less complicated phenomena must previously be studied.

The compound nature of the molecules of an organic body, and the phenomena presented by them when in

relation with other matters, point out the true cause of these transformations. Evidence is afforded even by simple bodies, that in the formation of combinations, the force with which the combining elements adhere to one another is inversely proportional to the number of simple atoms in the compound molecule. Thus, protoxide of manganese, by absorption of oxygen, is converted into the sesquioxide, the peroxide, manganic and hyper-manganic acids, the number of atoms of oxygen being augmented by ½, by 1, by 2, and by 5. But all the oxygen contained in these compounds, beyond that which belongs to the protoxide, is bound to the manganese by a much more feeble affinity ; a red heat causes an evolution of oxygen from the peroxide, and the manganic and hyper-manganic acids cannot be separated from their bases without undergoing immediate decomposition.

There are many facts which prove that the most simple inorganic compounds are also the most stable, and undergo decomposition with the greatest difficulty, whilst those which are of a complex composition yield easily to changes and decompositions. The cause of this evidently is, that in proportion to the number of atoms which enter into a compound, the directions in which their attractions act will be more numerous.

Whatever ideas we may entertain regarding the infinite divisibility of matter in general, the existence of chemical proportions removes every doubt respecting the presence of certain limited groups or masses of matter which we have not the power of dividing. The particles of matter called equivalents in chemistry are not infinitely small, for they possess a weight, and are capable of arranging themselves in the most various ways, and of thus forming innumerable compound atoms. The pro-

perties of these compound atoms differ in organic nature, not only according to the form, but also in many instances according to the direction and place, which the simple atoms take in the compound molecules.

When we compare the composition of organic compounds with inorganic, we are quite amazed at the existence of combinations, in one single molecule of which, ninety or several hundred atoms or equivalents are united. Thus, the compound atom of an organic acid of very simple composition, acetic acid for example, contains twelve equivalents of simple elements ; one atom of kinovic acid contains 33, 1 of sugar 36, 1 of amygdalin 90, and 1 of stearic acid 138 equivalents. The component parts of animal bodies are infinitely more complex even than these.

Inorganic compounds differ from organic in as great a degree in their other characters as in their simplicity of constitution. Thus, the decomposition of a compound atom of sulphate of potash is aided by numerous causes, such as the power of cohesion, or the capability of its constituents to form solid, insoluble, or at certain temperatures volatile, compounds with the body brought into contact with it, and nevertheless a vast number of other substances produce in it not the slightest change. Now, in the decomposition of a complex organic atom, there is nothing similar to this.

The empirical formula of sulphate of potash is SKO_4. It contains only 1 eq. of sulphur, and 1 eq. of potassium. We may suppose the oxygen to be differently distributed in the compound, and by a decomposition we may remove a part or all of it, or replace one of the constituents of the compound by another substance. But we cannot produce a different arrangement of the atoms, because

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they are already disposed in the simplest form in which
it is possible for them to combine. Now, let us compare
the composition of sugar of grapes with the above : here
12 eq. of carbon, 12 eq. of hydrogen, and 12 eq. of
oxygen, are united together, and we know that they are
capable of combining with each other in the most various
ways. From the formula of sugar, we might consider
it either as a hydrate of carbon, wood, starch, or sugar
of milk, or further, as a compound of ether with alcohol
or of formic acid with sachulmin.*   Indeed we may
calculate almost all the known organic compounds des-
titute of nitrogen from sugar, by simply adding the
elements of water, or by replacing any one of its elemen-
tary constituents by a different substance. The elements
necessary to form these compounds are therefore con-
tained in the sugar, and they must also possess the power
of forming numerous combinations amongst themselves
by their mutual attractions.

Now, when we examine what changes sugar under-
goes when brought into contact with other bodies which
exercise a marked influence upon it, we find that these
changes are not confined to any narrow limits, like those
of inorganic bodies, but are in fact unlimited.

The elements of sugar yield to every attraction, and
to each in a peculiar manner. In inorganic compounds,
an acid acts upon a particular constituent of the body,
which it decomposes, by virtue of its affinity for that con-
stituent, and never resigns its proper chemical character,
in whatever form it may be applied. But when it acts upon
sugar, and induces great changes in that compound, it
does this, not by any superior affinity for a base existing in,

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* The black precipitate obtained by the action of hydrochloric acid
on sugar.

the sugar, but by disturbing the equilibrium in the mutual attraction of the elements of the sugar amongst themselves. Muriatic and sulphuric acids, which differ so much from one another both in characters and composition, act in the same manner upon sugar. But the action of both varies according to the state in which they are; thus they act in one way when dilute, in another when concentrated, and even differences in their temperature cause a change in their action. Thus, sulphuric acid of a moderate degree of concentration converts sugar into a black carbonaceous matter, forming at the same time acetic and formic acids. But when the acid is more diluted, the sugar is converted into two brown substances, both of them containing carbon and the elements of water. Again, when sugar is subjected to the action of alkalies, a whole series of different new products are obtained; while oxidizing agents, such as nitric acid, produce from it carbonic acid, acetic acid, oxalic acid, formic acid, and many other products which have not yet been examined.

If from the facts here stated we estimate the power with which the elements of sugar are united together, and judge of the force of their attraction by the resistance which they offer to the action of bodies brought into contact with them, we must regard the atom of sugar as belonging to that class of compound atoms, which exist only by the *vis inertiæ* of their elements. Its elements seem merely to retain passively the position and condition in which they had been placed, for we do not observe that they resist a change of this condition by their own mutual attraction, as is the case with sulphate of potash.

Now it is only such combinations as sugar, combinations therefore which possess a very complex molecule,

which are capable of undergoing the decompositions named fermentation and putrefaction.

We have seen that metals acquire a power which they do not of themselves possess, namely, that of decomposing water and nitric acid, by simple contact with other metals in the act of chemical combination. We have also seen, that peroxide of hydrogen and the persulphuret of the same element, in the act of decomposition, cause other compounds of a similar kind, but of which the elements are much more strongly combined, to undergo the same decomposition, although they exert no chemical affinity or attraction for them or their constituents. The cause which produces these phenomena will be also recognised, by attentive observation, in those matters which excite fermentation or putrefaction. All bodies in the act of combination or decomposition have the property of inducing those processes ; or, in other words, of causing a disturbance of the statical equilibrium in the attractions of the elements of complex organic molecules, in consequence of which those elements group themselves anew according to their special affinities.

The proofs of the existence of this cause of action can be easily produced; they are found in the characters of the bodies which effect fermentation. and putrefaction, and in the regularity with which the distribution of the elements takes place in the subsequent transformations. This regularity depends exclusively on the unequal affinity which they possess for each other in an isolated condition. The action of water on wood, charcoal, and cyanogen, the simplest of the compounds of nitrogen, suffices to illustrate the whole of the transformations of organic bodies; of those in which nitrogen is a constituent, and of those in which it is absent.

CHAPTER IV.

ON THE TRANSFORMATION OF BODIES WHICH DO NOT CONTAIN NITROGEN AS A CONSTITUENT, AND OF THOSE IN WHICH IT IS PRESENT.

WHEN oxygen and hydrogen combined in equal equivalents, as in steam, are conducted over charcoal, heated to the temperature at which it possesses the power to enter into combination with one of these elements, a decomposition of the steam ensues. An oxide of carbon (either carbonic oxide or carbonic acid) is under all circumstances formed, while the hydrogen of the water is liberated, or, if the temperature be sufficient, unites with the carbon, forming carburetted hydrogen. Accordingly, the carbon is shared between the elements of the water, the oxygen and hydrogen. Now a participation of this kind, but even more complete, is observed in every transformation, whatever be the nature of the causes by which it is effected.

Acetic and meconic* acids suffer a true transformation under the influence of heat, that is, their component elements are disunited, and form new compounds without any of them being singly disengaged. Acetic acid is converted into acetone and carbonic acid ($C4$ $H3$ $O3 =$ $C3$ $H3$ O $+$ $CO2$), and meconic acid into carbonic acid and komenic acid; whilst, by the influence of a higher

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* An acid existing in opium, and named from the Greek for poppy.

temperature, the latter is further decomposed into pyro-
meconic acid and carbonic acid.

Now in these cases the carbon of the bodies decom-
posed is shared between the oxygen and hydrogen; part
of it unites with the oxygen and forms carbonic acid,
whilst the other portion enters into combination with
the hydrogen, and an oxide of a carbo-hydrogen is formed,
in which all the hydrogen is contained.

In a similar manner, when alcohol is exposed to a
gentle red heat, its carbon is shared between the ele-
ments of the water—an oxide of a carbo-hydrogen which
contains all the oxygen, and some gaseous compounds of
carbon and hydrogen being produced.

It is evident that during transformations caused by
heat, no foreign affinities can be in play, so that the new
compounds must result merely from the elements arrang-
ing themselves, according to the degree of their mutual
affinities, into new combinations which are constant and
unchangeable in the conditions under which they were
originally formed, but undergo changes when these con-
ditions become different.   If we compare the products
of two bodies, similar in composition but different
in properties, which are subjected to transformations
by two different causes, we find that the manner in
which the atoms are transposed, is absolutely the same
in both.

In the transformation of wood in marshy soils, by
what we call putrefaction, its carbon is shared between
the oxygen and hydrogen of its own substance, and of
the water—carburetted hydrogen is consequently evolved,
as well as carbonic acid, both of which compounds have
an analogous composition (CH_2, CO_2).

Thus also in that transformation of sugar, which is

called fermentation, its elements are divided into two portions; the one, carbonic acid, which contains $\frac{2}{3}$ of the oxygen of sugar; and the other, alcohol, which contains all its hydrogen.

In the transformation of acetic acid produced by a red heat, carbonic acid, which contains $\frac{2}{3}$ of the oxygen of the acetic acid, is formed, and acetone, which contains all its hydrogen.

It is evident from these facts, that the elements of a complex compound are left to their special attractions whenever their equilibrium is disturbed, from whatever cause this disturbance may proceed. It appears also, that the subsequent distribution of the elements, so as to form new combinations, always takes place in the same way, with this difference only, that the nature of the products formed is dependent upon the number of atoms of the elements which enter into action; or, in other words, that the products differ *ad infinitum*, according to the composition of the original substance.

ON THE TRANSFORMATION OF BODIES CONTAINING NITROGEN.

When those substances are examined which are most prone to fermentation and putrefaction, it is found that they are all, without exception, bodies which contain nitrogen. In many of these compounds, a transposition of their elements occurs spontaneously as soon as they cease to form part of a living organism; that is, when they are drawn out of the sphere of attraction in which alone they are able to exist.

There are, indeed, bodies destitute of nitrogen, which possess a certain degree of stability only when in com-

bination, but which are unknown in an isolated condition, because their elements, freed from the power by which they were held together, arrange themselves according to their own natural attractions.   Hypermanganic, manganic, and hyposulphurous acids, belong to this class of substances, which however are rare.

The case is very different with azotised bodies.   It would appear that there is some peculiarity in the nature of nitrogen, which gives its compounds the power to decompose spontaneously with so much facility.   Now, nitrogen is known to be the most indifferent of all the elements; it evinces no particular attraction to any one of the simple bodies ; and this character it preserves in all its combinations, a character which explains the cause of its easy separation from the matters with which it is united.

It is only when the quantity of nitrogen exceeds a certain limit, that azotised compounds have some degree of permanence, as is the case with melamin, ammelin, &c.   Their liability to change is also diminished, when the quantity of nitrogen is very small in proportion to that of the other elements with which it is united, so that their mutual attractions preponderate.

This easy transposition of atoms is best seen in the fulminating silvers, in fulminating mercury, in the iodide or chloride of nitrogen, and in all fulminating compounds.

All other azotised substances acquire the same power of decomposition, when the elements of water are brought into play ; and indeed, the greater part of them are not capable of transformation, while this necessary condition to the transposition of their atoms is absent.   Even the compounds of nitrogen, which are most liable to

change, such as those which are found in animal bodies, do not enter into a state of putrefaction when dry.

The result of the known transformations of azotised substances proves, that the water does not merely act as a medium in which motion is permitted to the elements in the act of transposition, but that its influence depends on chemical affinity. When the decomposition of such substances is effected with the assistance of water, their nitrogen is invariably liberated in the form of ammonia. This is a fixed rule without any exceptions, whatever may be the cause which produces the decompositions. All organic compounds containing nitrogen, evolve the whole of that element in the form of ammonia when acted on by alkalies. Acids, and increase of temperature, produce the same effect. It is only when there is a deficiency of water or its elements, that cyanogen or other azotised compounds are produced.

From these facts it may be concluded, that ammonia is the most stable compound of nitrogen; and that hydrogen and nitrogen possess a degree of affinity for each other surpassing the attraction of the latter body for any other element.

Already, in considering the transformations of substances destitute of nitrogen, we have recognised the great affinity of carbon for oxygen as a powerful cause for effecting the disunion of the elements of a complex organic atom in a definite manner. But carbon is also invariably contained in azotised organic compounds, while the great affinity of nitrogen for hydrogen furnishes a new and powerful cause, facilitating the transposition of their component parts. Thus, in the bodies which do not contain nitrogen we have one element, and in those in which that substance is present, two elements, which

mutually share the elements of water. Hence there are two opposite affinities at play, which mutually strengthen each other's action.

Now we know that the most powerful attractions may be overcome by the influence of two affinities. Thus, a decomposition of alumina may be effected with the greatest facility, when the affinity of charcoal for oxygen, and of chlorine for aluminium, are both put in action, although neither of these alone has any influence upon it. There is in the nature and constitution of the compounds of nitrogen a kind of tension of their component parts, and a strong disposition to yield to transformations, which effect spontaneously the transposition of their atoms on the instant that water or its elements are brought in contact with them.

The characters of the hydrated cyanic acid, one of the simplest of all the compounds of nitrogen, are perhaps the best adapted to convey a distinct idea of the manner in which the atoms are disposed of in transformations. This acid contains nitrogen, hydrogen, and oxygen in such proportions, that the addition of a certain quantity of the elements of water is exactly sufficient to cause the oxygen contained in the water and acid to unite with the carbon and form carbonic acid, and the hydrogen of the water to combine with the nitrogen and form ammonia. The most favourable conditions for a complete transformation are, therefore, associated in these bodies, and it is well known, that the disunion takes place on the instant in which the cyanic acid and water are brought into contact, the mixture being converted into carbonic acid and ammonia, with brisk effervescence.

This decomposition may be considered as the type of the transformations of all azotised compounds; it is

putrefaction in its simplest and most perfect form, because the new products, the carbonic acid and ammonia, are incapable of further transformations.

Putrefaction assumes a totally different and much more complicated form, when the products, which are first formed, undergo a further change. In these cases the process consists of several stages, of which it is impossible to determine when one ceases and the other begins.

The transformations of cyanogen, a body composed of carbon and nitrogen, and the simplest of all the compounds of nitrogen, will convey a clear idea of the great variety of products which are produced in such a case : it is the only example of the putrefaction of an azotised body which has been at all accurately studied.

A solution of cyanogen in water becomes turbid after a short time, and deposits a black or brownish black matter, which is a combination of ammonia with another body, produced by the simple union of cyanogen with water. This substance is insoluble in water, and is thus enabled to resist further change.

A second transformation is effected by the cyanogen being shared between the elements of the water, in consequence of which *cyanic acid* is formed by a certain quantity of the cyanogen combining with the oxygen of the water, while *hydrocyanic acid* is also formed by another portion of the cyanogen uniting with the hydrogen which was liberated.

Cyanogen experiences a third transformation, by which a complete disunion of its elements takes place, these being divided between the constituents of the water. *Oxalic acid* is the one product of this disunion, and *ammonia* the other.

Cyanic acid, the formation of which has been mentioned above, cannot exist in contact with water, being decomposed immediately into carbonic acid and ammonia. The cyanic acid, however, newly formed in the decomposition of cyanogen, escapes this decomposition, by entering into combination with the free ammonia, by which *urea* is produced.

The hydrocyanic acid is also decomposed into a brown matter which contains hydrogen and cyanogen, the latter in greater proportion than it does in the gaseous state. Oxalic acid, urea, and carbonic acid, are also formed by its decomposition, and *formic acid* and *ammonia* are produced by the decomposition of its radical.

Thus, a substance into the composition of which only two elements (carbon and nitrogen) enter, yields eight totally different products. Several of these products are formed by the transformation of the original body, its elements being shared between the constituents of water; others are produced in consequence of a further disunion of those first formed. The urea and carbonate of ammonia are generated by the combination of two of the products, and in their formation the whole of the elements have assisted.

These examples show that the results of decomposition by fermentation or putrefaction comprehend very different phenomena. The first kind of transformation is the transposition of the elements of one complex compound, by which new compounds are produced with or without the assistance of the elements of water. In the products newly formed in this manner, either the same proportions of those component parts which were contained in the matter before transformation, are found, or with them, an excess, consisting of the constituents of

water, which had assisted in promoting the disunion of
the elements.

The second kind of transformations consists of the
transpositions of the atoms of two or more complex com-
pounds, by which the elements of both arrange themselves
mutually into new products, with or without the coöpe-
ration of the elements of water.   In this kind of trans-
formations, the new products contain the sum of the
constituents of all the compounds which had taken a part
in the decomposition.

The first of these two modes of decomposition is
that designated *fermentation*, the second *putrefaction;*
and when these terms are used in the following pages,
it will always be to distinguish the two processes above
described, which are so different in their results.

CHAPTER V.

FERMENTATION OF SUGAR.

The peculiar decomposition which sugar suffers may be viewed as a type of all the transformations designated fermentation*.

Thénard obtained from 100 grammes of cane-sugar 0·5262 of absolute alcohol. 100 parts of sugar from the cane yield, therefore, 103·89 parts of carbonic acid and alcohol. The entire carbon in these products is equal to 42 parts, which is exactly the quantity originally contained in the sugar.

The analysis of sugar from the cane proves that it contains the elements of carbonic acid and alcohol, *minus* 1 atom of water. The alcohol and carbonic acid produced by the fermentation of a certain quantity of sugar, contain together one equivalent of oxygen, and one equi-

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* When yeast is made into a thin paste with water, and 1 cubic centimetre of this mixture introduced into a graduated glass receiver filled with mercury, in which are already 19 grammes of a solution of cane-sugar, containing 1 gramme of pure solid sugar; it is found, after the mixture has been exposed for 24 hours to a temperature of from 20 to 25 C. (68—77 F.), that a volume of carbonic acid has been formed, which, at 0° C. (32° F.) and an atmospheric pressure indicated by 0·76 metre Bar. would be from 245 to 250 cubic centimetres. But to this quantity we must add 11 cubic centimetres of carbonic acid, with which the 11 grammes of liquid would be saturated, so that in all 255—259 cubic centimetres of carbonic acid are obtained. This volume of carbonic acid corresponds to from 0·503 to 0·5127 grammes by weight.

valent of hydrogen; the elements, therefore, of one equi-
valent of water more than the sugar contained. The
excess of weight in the products is thus explained most
satisfactorily; it is owing, namely, to the elements of
water having taken part in the metamorphosis of the
sugar.

It is known that 1 atom of sugar contains 12 equiva-
lents of carbon, both from the proportions in which it
unites with bases, and from the composition of saccharic
acid the product of its oxidation. Now none of these
atoms of carbon are contained in the sugar as carbonic
acid, because the whole quantity is obtained as oxalic
acid when sugar is treated with hypermanganate of
potash (Gregory); and as oxalic acid is a lower degree
of the oxidation of carbon than carbonic acid, it is im-
possible to conceive that the lower degree should be pro-
duced from the higher, by means of one of the most
powerful agents of oxidation which we possess.

It can be also proved that the hydrogen of the sugar
does not exist in it in the form of alcohol, for it is con-
verted into water and a kind of carbonaceous matter,
when treated with acids, particularly with such as contain
no oxygen; and this manner of decomposition is never
suffered by a compound of alcohol.

Sugar contains, therefore, neither alcohol nor car-
bonic acid, so that these bodies must be produced by a
different arrangement of its atoms, and by their union
with the elements of water.

In this metamorphosis of sugar, the elements of
the yeast, by contact with which its fermentation was
effected, take no appreciable part in the transposition of
the elements of the sugar; for in the products resulting

from the action, we find no component part of this substance.

We may now study the fermentation of a vegetable juice, which contains not only saccharine matter, but also such substances as albumen and gluten. The juices of parsneps, beet-roots, and onions, are well adapted for this purpose. When such a juice is mixed with yeast at common temperatures, it ferments like a solution of sugar. Carbonic acid gas escapes from it with effervescence, and in the liquid, alcohol is found in quantity exactly corresponding to that of the sugar originally contained in the juice. But such a juice undergoes spontaneous decomposition at a temperature of from 95° to 104° (35°—40° C.). Gases possessing an offensive smell are evolved in considerable quantity, and when the liquor is examined after the decomposition is completed, no alcohol can be detected. The sugar has also disappeared, and with it all the azotised compounds which existed in the juice previously to its fermentation. Both were decomposed at the same time; the nitrogen of the azotised compounds remains in the liquid as ammonia, and, in addition to it, there are three new products, formed from the component parts of the juice. One of these is lactic acid, the slightly volatile compound found in the animal organism; the other is the crystalline body which forms the principal constituent of manna; and the third is a mass resembling gum-arabic, which forms a thick viscous solution with water. These three products weigh more than the sugar contained in the juice, even without calculating the weight of the gaseous products. Hence they are not produced from the elements of the sugar alone. None of these three substances could be

detected in the juice before fermentation. They must, therefore, have been formed by the interchange of the elements of the sugar with those of the foreign substances also present. It is this mixed transformation of two or more compounds which receives the special name of *putrefaction*.

YEAST OR FERMENT.

When attention is directed to the condition of those substances which possess the power of inducing fermentation and putrefaction in other bodies, evidences are found in their general characters, and in the manner in which they combine, that they all are bodies, the atoms of which are in the act of transposition.

The characters of the remarkable matter which is deposited in an insoluble state during the fermentation of beer, wine, and vegetable juices may first be studied.

This substance, which has been called *yeast* or *ferment*, from the power which it possesses of causing fermentation in sugar, or saccharine vegetable juices, possesses all the characters of a *compound of nitrogen in the state of putrefaction and eremacausis.*

Like wood in the state of eremacausis, yeast converts the oxygen of the surrounding air into carbonic acid, but it also evolves this gas from its own mass, like bodies in the state of putrefaction. (Colin.) When kept under water, it emits carbonic acid, accompanied by gases of an offensive smell, (Thénard,) and is at last converted into a substance resembling old cheese. (Proust.) But when its own putrefaction is completed, it has no longer the power of inducing fermentation in other bodies. The presence of water is quite, necessary for sustaining the

acid; but when the urine has undergone putrefaction, no trace of it can be discovered. The urine of man contains a considerable quantity of urea; but when the urine putrefies, the urea entirely disappears. When urea is added to a solution of sugar in the state of fermentation, it is decomposed into carbonic acid and ammonia. No asparagin can be detected in a putrefied infusion of asparagin, liquorice-root, or the root of marshmallow (*Althæa officinalis.*)

It has already been mentioned, that the strong affinity of nitrogen for hydrogen, and that of carbon for oxygen, are the cause of the facility with which the elements of azotised compounds are disunited; those affinities aiding each other, inasmuch as by virtue of them different elements of the compounds strive to take possession of the different elements of water. Now since it is found that no body destitute of nitrogen possesses, when pure, the property of decomposing spontaneously whilst in contact with water, we must ascribe this property which azotised bodies possess in so eminent a degree, to something peculiar in the nature of the compounds of nitrogen, and to their constituting, in a certain measure, more highly organised atoms.

Every azotised constituent of the animal or vegetable organism runs spontaneously into putrefaction, when exposed to moisture and a high temperature.

Azotised matters are, accordingly, the only causes of fermentation and putrefaction in vegetable substances.

Putrefaction, on account of its effects, as a mixed transformation of many different substances, may be classed with the most powerful processes of deoxidation, by which the strongest affinities are overcome.

When a solution of gypsum in water is mixed with a

decoction of sawdust, or any other organic matter capable
of putrefaction, and preserved in well-closed vessels, it is
found after some time, that the solution contains no more
sulphuric acid, but in its place carbonic and free hydro-
sulphuric acid, between which the lime of the gypsum is
shared. In stagnant water containing sulphates in solu-
tion, crystallised pyrites is observed to form on the de-
caying roots.

Now we know that in the putrefaction of wood under
water, when air therefore is excluded, a part of its carbon
combines with the oxygen of the water, as well as with
the oxygen which the wood itself contains ; whilst its
hydrogen and that of the decomposed water are liberated
either in a pure state, or as carburetted hydrogen. The
products of this decomposition are of the same kind as
those generated when steam is conducted over red-hot
charcoal.

It is evident, that if with the water a substance contain-
ing a large quantity of oxygen, such as sulphuric acid, be
also present, the matters in the state of putrefaction will
make use of the oxygen of that substance as well as that of
the water, in order to form carbonic acid; and the sulphur
and hydrogen being set free will combine whilst in the
nascent state, producing hydrosulphuric acid, which will
be again decomposed if metallic oxides be present ;and
the results of this second decomposition will be water and
metallic sulphurets.

The putrefied leaves of woad (*Isatis tinctoria*), in con-
tact with indigo-blue water, and alkalies, suffer further
decomposition, and the indigo is deoxidised and dissolved.

The mannite formed by the putrefaction of beet-roots
and other plants which contain sugar, contains the same
number of equivalents of carbon and hydrogen as the

sugar of grapes, but two atoms less of oxygen; and it is
highly probable that it is produced from sugar of grapes,
contained in those plants, in precisely the same manner
as indigo-blue is converted into deoxidised white indigo.

During the putrefaction of gluten, carbonic acid and
pure hydrogen gas are evolved; phosphate, acetate,
caseate, and lactate of ammonia being at the same time
produced in such quantity, that the further decompo-
sition of the gluten ceases. But when the supply of
water is renewed, the decomposition begins again, and
in addition to the salts just mentioned, carbonate of am-
monia and a white crystalline matter resembling mica
(caseous oxide) are formed, together with hydrosulphate
of ammonia, and a mucilaginous substance coagulable by
chlorine. *Lactic acid* is almost always produced by the
putrefaction of organic bodies.

We may now compare fermentation and putrefaction
with the decomposition which organic compounds suffer
under the influence of a high temperature. Dry distil-
lation would appear to be a process of combustion or
oxidation going on in the interior of a substance, in
which a part of the carbon unites with all or part of the
oxygen of the compound, while other new compounds
containing a large proportion of hydrogen are necessarily
produced. Fermentation may be considered as a process
of combustion or oxidation of a similar kind, taking place
in a liquid between the elements of *the same matter*, at a
very slightly elevated temperature; and putrefaction as a
process of oxidation, in which the oxygen of *all* the sub-
stances present comes into play.

CHAPTER VI.

EREMACAUSIS, OR DECAY.

In organic nature, besides the processes of decomposition named fermentation and putrefaction, another and not less striking class of changes occurs, which bodies suffer from the influence of the air. This is the act of gradual combination of the combustible elements of a body with the oxygen of the air ; a slow combustion or oxidation, to which we shall apply the term of *eremacausis*.

The conversion of wood into humus, the formation of acetic acid out of alcohol, nitrification, and numerous other processes, are of this nature. Vegetable juices of every kind, parts of animal and vegetable substances, moist sawdust, blood, &c., cannot be exposed to the air, without suffering immediately a progressive change of colour and properties, during which oxygen is absorbed. These changes do not take place when water is excluded, or when the substances are exposed to the temperature of 32° ; and it has been observed that different bodies require different degrees of heat, in order to effect the absorption of oxygen, and, consequently, their eremacausis. The property of suffering this change is possessed in the highest degree by substances containing nitrogen.

When vegetable juices are evaporated by a gentle heat

in the air, a brown or brownish-black substance is precipitated as a product of the action of oxygen upon them. This substance, which appears to possess similar properties from whatever juice it is obtained, has received the name of *extractive matter ;* it is insoluble or very sparingly soluble in water, but is dissolved with facility by alkalies. By the action of air on solid animal or vegetable matters, a similar pulverulent brown substance is formed, and is known by the name of *humus.*

The conditions which determine the commencement of eremacausis are of various kinds. Many organic substances, particularly such as are mixtures of several more simple matters, oxidise in the air when simply moistened with water; others, not until they are subjected to the action of alkalies ; but the greatest part of them undergo this state of slow combustion or oxidation, when brought in contact with other decaying matters.

The eremacausis of an organic matter is retarded or completely arrested by all those substances which prevent fermentation or putrefaction. Mineral acids, salts of mercury, aromatic substances, empyreumatic oils, and oil of turpentine, possess a similar action in this respect. The latter substances have the same effect on decaying bodies as on phosphuretted hydrogen, the spontaneous inflammability of which they destroy.

Many bodies which do not decay when moistened with water, enter into eremacausis when in contact with an alkali. Gallic acid, hæmatin, and many other compounds, may be dissolved in water and yet remain unaltered ; but if the smallest quantity of a free alkali is present, they acquire the property of attracting oxygen, and are converted into a brown substance like humus, evolving very frequently at the same time carbonic acid. (Chevreul.)

A very remarkable kind of eremacausis takes place in many vegetable substances, when they are exposed to the influence of air, water, and ammonia. They absorb oxygen very rapidly, and form splendid violet or red-coloured liquids, as in the case of orcin and erythrin. They now contain an azotised substance, not in the form of ammonia.

All these facts show that the action of oxygen seldom affects the carbon of decaying substances, and this cor-responds exactly to what happens in combustion at high temperatures. It is well known, for example, that when no more oxygen is admitted to a compound of carbon and hydrogen than is sufficient to combine with its hydrogen, the carbon is not burned, but is separated as lamp-black; while, if the quantity of oxygen is not sufficient even to consume all the hydrogen, new compounds are formed, such as naphthalin and similar matters, which contain a smaller proportion of hydrogen than those compounds of carbon and hydrogen which previously existed in the combustible substance.

There is no example of carbon combining directly with oxygen at common temperatures, but numerous facts show that hydrogen, in certain states of condensation, possesses that property. Lamp-black which has been heated to redness may be kept in contact with oxygen gas, without forming carbonic acid; but lamp-black, impregnated with oils which contain a large proportion of hydrogen, gradu-ally becomes warm, and inflames spontaneously. The spontaneous inflammability of the charcoal used in the fabrication of gunpowder has been correctly ascribed to the hydrogen which it contains in considerable quantity; for during its reduction to powder, no trace of carbonic acid can be detected in the air surrounding it; it is not

formed until the temperature of the mass has reached a red heat. The heat which produces the inflammation is therefore not caused by the oxidation of the carbon.

The substances which undergo eremacausis may be divided into two classes. The first class comprehends those substances which unite with the oxygen of the air, without evolving carbonic acid; and the second, such as emit carbonic acid by absorbing oxygen.

When the oil of bitter almonds is exposed to the air, it absorbs two equivalents of oxygen, and is converted into benzoic acid; but half of the oxygen absorbed combines with the hydrogen of the oil, and forms water, which remains in union with the anhydrous benzoic acid *.

But, although it appears very probable that the oxygen acts primarily and principally upon hydrogen, the most combustible constituent of organic matter in the state of decay; still it cannot thence be concluded that the carbon is quite devoid of the power to unite with oxygen, when every particle of it is surrounded with hydrogen, an

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* According to the experiments of Döbereiner, 100 parts of pyrogallic acid absorb 38·09 parts of oxygen when in contact with ammonia and water; the acid being changed in consequence of this absorption into a mouldy substance, which contains less oxygen than the acid itself. It is evident that the substance which is formed is not a higher oxide; and it is found, on comparing the quantity of the oxygen absorbed with that of the hydrogen contained in the acid, that they are exactly in the proportions for forming water.

When colourless orcin is exposed together with ammonia to the contact of oxygen gas, the beautiful red-coloured orcein is produced. Now, the only changes which take place here are, that the absorption of oxygen by the elements of orcin and ammonia causes the formation of water; 1 equivalent of orcin $C18$ $H12$ $O8$, and 1 equivalent of ammonia $NH3$, absorb 5 equivalents of oxygen, and 5 equivalents of water are produced, the composition of orcein being $C18$ $H10$ $O8$ N. (Dumas.) In this case it is evident, that the oxygen absorbed has united merely with the hydrogen.

element with which the oxygen combines with greater
facility.

We know, on the contrary, that although nitrogen
cannot be made to combine with oxygen directly, yet it is
oxidised and forms nitric acid, when mixed with a large
quantity of hydrogen, and burned in oxygen gas. In this
case its affinity is evidently increased by the combustion
of the hydrogen, which is in fact communicated to it. It
is conceivable, that in a similar manner, the carbon may
be directly oxidised in several cases, obtaining from its
contact with hydrogen in eremacausis a property which it
does not itself possess at common temperatures. But the
formation of carbonic acid during the eremacausis of
bodies containing hydrogen, must in most cases be
ascribed to another cause. It appears to be formed in a
manner similar to the formation of acetic acid, by the
eremacausis of saliculite of potash *.

An alkaline solution of hæmatin being exposed to an
atmosphere of oxygen, 0·2 grm. absorb 28·6 cubic cen-
timeters of oxygen gas in twenty-four hours, the alkali
acquiring at the same time 6 cubic centimeters of carbonic
acid. (Chevreul.) But these 6 cubic centimeters of car-
bonic acid contain only an equal volume of oxygen, so
that it is certain from this experiment that $\frac{3}{4}$ of the oxygen
absorbed have not united with the carbon. It is highly
probable, that during the oxidation of the hydrogen, a
portion of the carbon had united with the oxygen con-
tained in the hæmatin, and had separated from the other
elements as carbonic acid.

The experiments of De Saussure upon the decay of

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* This salt, when exposed to a moist atmosphere, absorbs 3 atoms of
oxygen; *melanic acid* is produced, a body resembling humus, in conse-
quence of the formation of which, the elements of 1 atom of acetic acid
are separated from the saliculous acid.

woody fibre show that such a separation is quite possible. Moist woody fibre evolved one volume of carbonic acid for every volume of oxygen which it absorbed. It has just been mentioned that carbonic acid contains its own volume of oxygen. Now, woody fibre contains carbon and the elements of water, so that the result of the action of oxygen upon it is exactly the same as if pure charcoal had combined directly with oxygen. But the characters of woody fibre show that the elements of water are not contained in it in the form of water; for were this the case, starch, sugar, and gum must also be considered as hydrates of carbon.

But if the hydrogen does not exist in woody fibre in the form of water, the direct oxidation of the carbon cannot be considered as at all probable, without rejecting all the facts established by experiment regarding the process of combustion at low temperatures.

If we examine the action of oxygen upon a substance containing a large quantity of hydrogen, such as alcohol, we find most distinctly, that the direct formation of carbonic acid is the last stage of its oxidation, and that it is preceded by a series of changes, the last of which is a complete combustion of the hydrogen. Aldehyde, acetic, formic, oxalic, and carbonic acids, form a connected chain of products arising from the oxidation of alcohol; and the successive changes which this fluid experiences from the action of oxygen may be readily traced in them. Aldehyde is alcohol *minus* hydrogen; acetic acid is formed by the direct union of aldehyde with oxygen. Formic acid and water are formed by the union of acetic acid with oxygen. When all the hydrogen is removed from this formic acid, oxalic acid is produced; and the latter acid is converted into carbonic acid by uniting with an addi-

tional portion of oxygen. All these products appear to
be formed simultaneously, by the action of oxidising
agents on alcohol; but it can scarcely be doubted, that
the formation of the last product, the carbonic acid, does
not take place until all the hydrogen has been abstracted.

The absorption of oxygen by drying oils certainly does
not depend upon the oxidation of their carbon ; for in raw
nut-oil, for example, which was not free from mucilage
and other substances, only twenty-one volumes of carbonic
acid were formed for every 146 volumes of oxygen gas
absorbed.

It must be remembered, that combustion or oxidation
at low temperatures produces results quite similar to com-
bustion at high temperatures *with limited access of air.*
The most combustible element of a compound, which is
exposed to the action of oxygen, must become oxidised
first, for its superior combustibility is caused by its being
enabled to unite with oxygen at a temperature at which
the other elements cannot enter into that combination ;
this property having the same effect as a greater affinity.

The combustibility of potassium is no measure of its
affinity for oxygen; we have reason to believe that the
attraction of magnesium and aluminium for oxygen is
greater than that of potassium for the same element; but
neither of those metals oxidises either in air or water at
common temperatures, whilst potassium decomposes water
with great violence, and appropriates its oxygen.

Phosphorus and hydrogen combine with oxygen at
ordinary temperatures, the first in moist air, the second
when in contact with finely-divided platinum; while
charcoal requires a red heat before it can enter into com-
bination with oxygen. It is evident that phosphorus and
hydrogen are more combustible than charcoal, that is,

that their affinity for oxygen *at common temperatures* is greater ; and this is not the less certain, because it is found, that carbon in certain other conditions shows a much greater affinity for oxygen than either of those substances.

In putrefaction, the conditions are evidently present under which the affinity of carbon for oxygen comes into play ; neither expansion, cohesion, nor the gaseous state, opposes it, whilst in eremacausis all these restraints have to be overcome.

The evolution of carbonic acid, during the decay or eremacausis of animal or vegetable bodies which are rich in hydrogen, must accordingly be ascribed to a transposition of the elements or disturbance in their attractions, similar to that which gives rise to the formation of carbonic acid in the processes of fermentation and putrefaction.

The eremacausis of such substances is, therefore, a decomposition analogous to the putrefaction of azotised bodies. For in these there are two affinities at play ; the affinity of nitrogen for hydrogen, and that of carbon for oxygen, and both facilitate the disunion of the elements. Now there are two affinities also in action in those bodies which decay with the evolution of carbonic acid. One of these affinities is the attraction of the oxygen of the air for the hydrogen of the substance, which corresponds to the attraction of nitrogen for the same element; and the other is the affinity of the carbon of the substance for its oxygen, which is constant under all circumstances.

When wood putrefies in marshes, carbon and oxygen are separated from its elements in the form of carbonic acid, and hydrogen in the form of carburetted hydrogen. But when wood decays or putrefies in the air, its hydro-

gen does not combine with carbon, but with oxygen, foi
which it has a much greater affinity at common tempera..
tures.

Now it is evident from the complete similarity of these
processes, that decaying and putrefying bodies can mutu-
ally replace one another in their reciprocal actions.

All putrefying bodies pass into the state of decay when
exposed freely to the air, and all decaying matters into
that of putrefaction when air is excluded. All bodies,
likewise, in a state of decay are capable of inducing putre-
faction in other bodies in the same manner as putrefying
bodies themselves do.

CHAPTER VII.

EREMACAUSIS OR DECAY OF BODIES DESTITUTE OF NITROGEN: FORMATION OF ACETIC ACID.

ALL those substances which appear to possess the property of entering spontaneously into fermentation and putrefaction, do not in reality suffer those changes without some previous disturbance in the attraction of their elements. Eremacausis always precedes fermentation and putrefaction, and it is not until after the absorption of a certain quantity of oxygen that the signs of a transformation in the interior of the substances show themselves.

It is a very general error to suppose that organic substances have the power of undergoing change spontaneously, *without the aid of an external cause.* When they are not in a state of change, it is necessary, before they can assume that state, that the existing equilibrium of their elements should be disturbed; and the most common cause of this disturbance is undoubtedly the atmosphere which surrounds all bodies.

The juices of the fruit or other part of a plant which very readily undergo decomposition, retain their properties unchanged as long as they are protected from immediate contact with the air, that is, as long as the cells or organs in which they are contained resist the influence of the air. It is not until after the juices have been exposed to the air, and have absorbed a certain quantity of

oxygen, that the substances dissolved in them begin to
be decomposed.

The beautiful experiments of Gay-Lussac upon the
fermentation of the juice of grapes, as well as the import-
ant practical improvements to which they have led, are
the best proofs that the atmosphere possesses an influence
upon the changes of organic substances. The juice of
grapes which were expressed under a receiver filled with
mercury, so that air was completely excluded, did not
ferment. But when the smallest portion of air was intro-
duced, a certain quantity of oxygen became absorbed, and
fermentation immediately began. Although the juice was
expressed from the grapes in contact with air, under the
conditions therefore necessary to cause its fermentation,
still this change did not ensue when the juice was heated
in close vessels to the temperature of boiling water.
When thus treated, it could be preserved for years with-
out losing its property of fermenting. A fresh exposure
to the air at any period caused it to ferment.

Animal food of every kind, and even the most delicate
vegetables, may be preserved unchanged if heated to the
temperature of boiling water in vessels from which the
air is completely excluded. Food thus prepared has been
kept for fifteen years, and upon opening the vessels after
this long time, has been found as fresh and well-flavoured
as when originally placed in them.

The action of the oxygen in these processes of decom-
position is very simple; it excites changes in the compo-
sition of the azotised matters dissolved in the juices:—
the mode of combination of the elements of those matters
undergoes a disturbance and change in consequence of
their contact with oxygen. The oxygen acts here in a
similar manner to the friction or motion which affects the

mutual decomposition of two salts, the crystallisation of salts from their solution, or the explosion of fulminating mercury. It causes the state of rest to be converted into a state of motion.

When this condition of intestine motion is once excited, the presence of oxygen is no longer necessary. The smallest particle of an azotised body in this act of decomposition exercises an influence upon the particles in contact with it, and the state of motion is thus propagated through the substance. The air may now be completely excluded, but the fermentation or putrefaction proceeds uninterruptedly to its completion. It has been remarked that the mere contact of carbonic acid is sufficient to produce fermentation in the juices of several fruits.

The contact of ammonia and alkalies in general may be mentioned amongst the chemical conditions which determine the commencement of eremacausis; for their presence causes many substances to absorb oxygen and to decay, in which neither oxygen nor alkalies alone produce that change.

Thus alcohol does not combine with the oxygen of the air at common temperatures. But a solution of potash in alcohol absorbs oxygen with much rapidity, and acquires a brown colour. The alcohol is found after a short time to contain acetic acid, formic acid, and the products of the decomposition of aldehyde by alkalies, including aldehyde resin, which gives the liquid a brown colour.

The most general condition for the production of eremacausis in organic matter is contact with a body already in the state of eremacausis or putrefaction. We have here an instance of true contagion; for the communica-

dissolving in nitric acid, in which the platinum becomes oxidised, by virtue of an inductive action exercised upon it by the silver in the act of its oxidation. The hydrogen of the alcohol is oxidised at the expense of the oxygen in contact with it, and forms water, evolving heat at the same time; the residue is aldehyde, a substance which has as great an affinity for oxygen as sulphurous acid, and combines, therefore, directly with it, producing acetic acid.

CHAPTER VIII.

WHEN azotised substances are burned at high temperatures, their nitrogen does not enter into direct combination with oxygen. The knowledge of this fact is of assistance in considering the process of the eremacausis of such substances. Azotised organic matter always contains carbon and hydrogen, both of which elements have a very strong affinity for oxygen.

Now nitrogen possesses a very feeble affinity for that element, so that its compounds during their combustion present analogous phenomena to those which are observed in the combustion of substances containing a large proportion of hydrogen and carbon ; a separation of the carbon of the latter substances in an uncombined state takes place, and in the same way the substances containing nitrogen give out that element in its gaseous form.

When a moist azotised animal matter is exposed to the action of the air, ammonia is always liberated ; nitric acid is never formed.

But when alkalies or alkaline bases are present, a union of oxygen with the nitrogen takes place under the same circumstances, and nitrates are formed together with the other products of oxidation.

Although we see the most simple means and direct methods employed in the great processes of decomposition which proceed in nature, still we find that the final result depends on a succession of actions, which are essentially influenced by the chemical nature of the bodies submitted to decomposition.

When it is observed that the character of a substance remains unaltered in a whole series of phenomena, there is no reason to ascribe a new character to it, for the purpose of explaining a single phenomenon, especially where the explanation of that according to known facts offers no difficulty.

The most distinguished philosophers suppose that the nitrogen in an animal substance, when exposed to the action of air, water, and alkaline bases, obtains the power to unite directly with oxygen, and form nitric acid; but we are not acquainted with a single fact which justifies this opinion. It is only by the interposition of a large quantity of hydrogen in the state of combustion or oxidation, that nitrogen can be converted into an oxide.

When a compound of nitrogen and carbon, such as cyanogen, is burned in oxygen gas, its carbon alone is oxidised; and when it is conducted over a metallic oxide heated to redness, an oxide of nitrogen is very rarely produced, and never when the carbon is in excess. Kuhlmann found in his experiments, that it was only when cyanogen was mixed with an excess of oxygen gas, and conducted over spongy platinum, that nitric acid was generated.

Kuhlmann could not succeed in causing pure nitrogen to combine directly with oxygen, even under the most favourable circumstances; thus, with the aid of spongy platinum at different temperatures, no union took place.

The carbon in the cyanogen gas must, therefore, have given rise to the combustion of the nitrogen by induction.

On the other hand, we find that ammonia (a compound of hydrogen and nitrogen) cannot be exposed to the action of oxygen, without the formation of an oxide of nitrogen, and in consequence the production of nitric acid.

It is owing to the great facility with which ammonia is converted into nitric acid, that it is so difficult to obtain a correct determination of the quantity of nitrogen in a compound subjected to analysis, in which it is either contained in the form of ammonia, or from which ammonia is formed by an elevation of temperature. For when ammonia is passed over red-hot oxide of copper, it is converted, either completely or partially, into binoxide of nitrogen.

When ammoniacal gas is conducted over peroxide of manganese or iron heated to redness, a large quantity of nitrate of ammonia is obtained, if the ammonia be in excess; and the same decomposition happens when ammonia and oxygen are together passed over red-hot spongy platinum.

It appears, therefore, that the combination of oxygen with nitrogen occurs rarely during the combustion of compounds of the latter element with carbon, but that nitric acid is always a product when ammonia is present in the substance exposed to oxidation.

The cause wherefore the nitrogen in ammonia exhibits such a strong disposition to become converted into nitric acid is undoubtedly that the two products, which are the result of the oxidation of the constituents of ammonia, possess the power of uniting with one another. Now

this is not the case in the combustion of compounds of carbon and nitrogen; here one of the products is carbonic acid, which, on account of its gaseous form, must oppose the combination of the oxygen and nitrogen, by preventing their mutual contact, while the superior affinity of its carbon for the oxygen during the act of its formation will aid this effect.

When sufficient access of air is admitted during the combustion of ammonia, water is formed as well as nitric acid, and both of these bodies combine together. The presence of water may, indeed, be considered as one of the conditions essential to nitrification, since nitric acid cannot exist without it.

Eremacausis is a kind of putrefaction, differing from the common process of putrefaction, only in the part which the oxygen of the air plays in the transformations of the body in decay. When this is remembered, and when it is considered that in the transposition of the elements of azotised bodies their nitrogen assumes the form of ammonia, and that in this form, nitrogen possesses a much greater disposition to unite with oxygen than it has in any of its other compounds; we can with difficulty resist the conclusion, that ammonia is the general cause of nitrification on the surface of the earth.

Azotised animal matter is not, therefore, the immediate cause of nitrification; it contributes to the production of nitric acid only in so far as it is a slow and continued source of ammonia.

Now it has been shown in the former part of this work, that ammonia is always present in the atmosphere, so that nitrates might thence be formed in substances which themselves contained no azotised matter. It is known also, that porous substances possess generally the power

of condensing ammonia; there are few ferruginous earths which do not evolve ammoniacal products when heated to redness, and ammonia is the cause of the peculiar smell perceived upon moistening aluminous minerals. Thus, ammonia, by being a constituent of the atmosphere, is a very widely diffused cause of nitrification, which will come into play whenever the different conditions necessary for the oxidation of ammonia are combined. It is probable that other organic bodies in the state of eremacausis are the means of causing the combustion of ammonia; at all events, the cases are very rare, in which nitric acid is generated from ammonia, in the absence of all matter capable of eremacausis.

From the preceding observations on the causes of fermentation, putrefaction, and decay, we may now draw several conclusions calculated to correct the views generally entertained respecting the fermentation of wine and beer, and several other important processes of decomposition which occur in nature.

CHAPTER IX.

ON VINOUS FERMENTATION:—WINE AND BEER.

IT has already been mentioned, that fermentation is excited in the juice of grapes by the access of air; alcohol and carbonic acid being formed by the decomposition of the sugar contained in the fluid. But it was also stated, that the process once commenced, continues until all the sugar is completely decomposed, quite independently of any further influence of the air.

In addition to the alcohol and carbonic acid formed by the fermentation of the juice, there is also produced a yellow or grey insoluble substance, containing a large quantity of nitrogen. It is this body which possesses the power of inducing fermentation in a new solution of sugar, and which has in consequence received the name of *ferment*.

The alcohol and carbonic acid are produced from the elements of the sugar, and the ferment from those azotised constituents of the grape-juice, which have been termed gluten, or vegetable albumen.

According to the experiments of De Saussure, fresh impure gluten evolved, in five weeks, twenty-eight times its volume of a gas which consisted $\frac{3}{4}$ of carbonic acid, and $\frac{1}{4}$ of pure hydrogen gas; ammoniacal salts of several organic acids were formed at the same time. Water must, therefore, be decomposed during the putrefaction

of gluten; the oxygen of this water must enter into com-
bination with some of its constituents, whilst hydrogen
is liberated, a circumstance which happens only in de-
compositions of the most energetic kind. Neither fer-
ment nor any substance similar to it is formed in this
case; and we have seen that in the fermentation of sac-.
charine vegetable juices, no escape of hydrogen gas takes
place.

It is evident that the decomposition which gluten suf-
fers in an isolated state, and that which it undergoes when
dissolved in a vegetable juice, belong to two different
kinds of transformations. There is reason to believe
that its change to the insoluble state depends upon an
absorption of oxygen, for its separation in this state may
be effected, under certain conditions, by free exposure to
the air, without the presence of fermenting sugar. It is
known also that the juice of grapes, or vegetable juices in
general, become turbid when in contact with air, before
fermentation commences; and this turbidity is owing
to the formation of an insoluble precipitate of the same
nature as ferment.

From the phenomena which have been observed during
the fermentation of wort*, it is known with perfect cer-
tainty that ferment is formed from gluten at the same
time that the transformation of the sugar is effected; for
the wort contains the azotised matter of the corn, namely,
gluten in the same condition as it exists in the juice of
grapes.   The wort ferments by the addition of yeast, but
after its decomposition is completed, the quantity of fer-
ment or yeast is found to be thirty times greater than it
was originally.

* Wort is an infusion of malt; it consists of the soluble parts of this
substance dissolved in water.

Yeast from beer and that from wine, examined under the microscope, present the same form and general appearance. They are both acted on in the same manner by alkalies and acids, and possess the power of inducin fermentation anew in a solution of sugar; in short, they must be considered as identical.

The fact that water is decomposed during the putrefaction of gluten has been completely proved. The tendency of the carbon of the gluten to appropriate the oxygen of water must also always be in action, whether the gluten is decomposed in a soluble or insoluble state. These considerations, therefore, as well as the circumstance which all the experiments made on this subject appear to point out, that the conversion of gluten to the insoluble state is the result of oxidation, lead us to conclude that the oxygen consumed in this process is derived from the elements of water, or from the sugar which contains oxygen and hydrogen in the same proportion as water. At all events, the oxygen thus consumed in the fermentation of wine and beer is not taken from the atmosphere.

The fermentation of pure sugar in contact with yeast must evidently be a very different process from the fermentation of wort or *must* *.

In the former case, the yeast disappears during the decomposition of sugar; but in the latter, a transformation of gluten is effected at the same time, by which ferment is generated. Thus yeast is *destroyed* in the one case, but is *formed* in the other.

Now, since no free hydrogen gas can be detected during the fermentation of beer and wine, it is evident that the oxidation of the gluten, that is, its conversion into fer-

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* The liquid expressed from grapes when fully ripe is called *must*.

ment, must take place at the cost either of the oxygen of the water, or of that of the sugar; whilst the hydrogen which is set free must enter into new combinations, or by the deoxidation of the sugar, new compounds containing a large proportion of hydrogen, and small quantity of oxygen, together with the carbon of the sugar, must be formed.

It is well known that wine and fermented liquors generally contain, in addition to the alcohol, other substances which could not be detected before their fermentation, and which must have been formed, therefore, during that process in a manner similar to the production of mannite. The smell and taste which distinguish wine from all other fermented liquids are known to depend upon an ether of a volatile and highly combustible acid; the ether is of an oily nature, and has received the name *Œnanthic ether*. It is also ascertained that the smell and taste of brandy from corn and potato are owing to a peculiar oil, the *oil of potatoes*. This oil is more closely allied to alcohol in its properties, than to any other organic substance.

These bodies are products of the deoxidation of the substances dissolved in the fermenting liquids; they contain less oxygen than sugar or gluten, but are remarkable for the large quantity of hydrogen which enters into their composition.

Œnanthic acid contains an equal number of equivalents of carbon and hydrogen, exactly the same proportions of these elements, therefore, as sugar, but by no means the same proportion of oxygen. The oil of potatoes contains much more hydrogen.

Although it cannot be doubted that these volatile

liquids are formed by a mutual interchange of the elements of gluten and sugar, in consequence, therefore, of a true process of putrefaction, still it is certain that other causes exercise an influence upon their production and peculiarities.

The substances in wine to which its taste and smell are owing, are generated during the fermentation of the juice of such grapes as contain a certain quantity of tartaric acid; they are not found in wines which are free from all acid, or which contain a different organic acid, such as acetic acid.

The wines of warm climates possess no odour; wines grown in France have it in a marked degree, but in the wines from the Rhine the perfume is most intense. The kinds of grapes on the Rhine which ripen very late, and scarcely ever completely, such as the *Riessling* and *Orleans*, have the strongest perfume or *bouquet*, and contain, proportionally, a larger quantity of tartaric acid. The earlier grapes, such as the *Rulander*, and others, contain a large proportion of alcohol, and are similar to Spanish wines in their flavour, but they possess no *bouquet*.

The grapes grown at the Cape from Riesslings transplanted from the Rhine, produce an excellent wine, which does not however possess the aroma which distinguishes Rhenish wine.

It is evident from these facts, that the acid of wines, and their characteristic perfumes, have some connexion, for they are always found together; and it can scarcely be doubted that the presence of the former exercises a certain influence on the formation of the latter. This influence is very plainly observed in the fermentation of liquids which are quite free from tartaric acid, and par-

ticularly of those which are nearly neutral or alkaline, such as the mash * of potatoes or corn.

The brandy obtained from corn and potatoes contains an ethereal oil of a similar composition in both, to which these liquors owe their peculiar smell. This oil is generated during the fermentation of the mash; it exists ready formed in the fermented liquids, and distils over with alcohol, when a gentle heat is applied.

It is observed that a greater quantity of alcohol is obtained when the mash is made quite neutral by means of ashes, or carbonate of lime, but that the proportion of oil in the brandy is also increased.

Now it is known that brandy made from potato starch, which has been converted into sugar by dilute sulphuric acid, is completely free from the potato oil, so that this substance must be generated in consequence of a change suffered by the cellular tissue of the potatoes during their fermentation.

Experience has shown that the simultaneous fermentation or putrefaction of the cellular tissue, by which this oil is generated, may be completely prevented in the fabrication of brandy from corn†.

The same malt, which in the preparation of brandy yields a fluid containing the oil of which we are speaking, affords in the formation of beer a spirituous liquor, in which no trace of that oil can be detected. The principal difference in the preparation of the two liquids is, that in the fermentation of wort, an aromatic substance

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* *Mash* is the mixture of malt, potatoes, and water, in the *mash tun*, a large vessel in which it is infused.

† In the manufactory of M. Dubrunfaut, so considerable a quantity of this oil is obtained under certain circumstances from brandy made from potatoes, that it might be employed for the purpose of illuminating his whole manufactory.

(hops) is added, and it is certain that its presence modifies the transformations which take place. Now it is known that the volatile oil of mustard, and the empyreumatic oils, arrest completely the action of yeast; and although the oil of hops does not possess this property, still it diminishes, in a great degree, the influence of decomposing azotised bodies upon the conversion of alcohol into acetic acid. There is, therefore, reason to believe that some aromatic substances, when added to fermenting mixtures, are capable of producing very various modifications in the nature of the products generated.

Whatever opinion, however, may be held regarding the origin of the volatile odoriferous substances obtained in the fermentation of wine, it is quite certain that the characteristic smell of wine is owing to an ether of an organic acid, resembling one of the fatty acids (œnanthic ether).

It is only in liquids which contain other very soluble acids, that the fatty acids and œnanthic acids are capable of entering into combination with the ether of alcohol, and of thus producing compounds of a peculiar smell. This ether is found in all wines which contain free acid, and is absent from those in which no acids are present. This acid, therefore, is the means by which the smell is produced; since, without its presence, œnanthic ether could not be formed.

The greatest part of the oil of brandy made from corn consists of a fatty acid not converted into ether; it dissolves oxide of copper and metallic oxides in general, and combines with the alkalies.

The principal constituent of this oil is an acid identical in composition with œnanthic acid, but different in properties. (Mulder.)   It is formed in fermenting liquids,

which, if they be acid, contain only acetic acid, a body which has no influence in causing other acids to form ethers.

The oil of brandy made from potatoes is the hydrate of an organic base analogous to ether, and capable, therefore, of entering into combination with acids. It is formed in considerable quantity in fermenting liquids which are slightly alkaline; under circumstances, consequently, in which it is incapable of combining with an acid.

The products of the fermentation and putrefaction of neutral vegetable and animal matters are generally accompanied by substances of an offensive odour; but the most remarkable example of the generation of a true ethereal oil is seen in the fermentation of the *Herba centaurium minorius*, a plant which possesses no smell. When it is exposed in water to a slightly elevated temperature, it ferments, and emits an agreeable penetrating odour. By the distillation of the liquid, an ethereal oily substance of great volatility is obtained, which excites a pricking sensation in the eyes, and a flow of tears. (Büchner.)

The leaves of the tobacco plant present the same phenomena; when fresh, they possess very little or no smell. When they are subjected to distillation with water, a weak ammoniacal liquid is obtained, upon which a fatty crystallizable substance swims, which does not contain nitrogen, and is quite destitute of smell. But when the same plant, after being dried, is moistened with water, tied, together in small bundles, and placed in heaps, a peculiar process of decomposition takes place. Fermentation commences, and is accompanied by the absorption of oxygen; the leaves now become warm, and

emit the characteristic smell of prepared tobacco and snuff. When the fermentation is carefully promoted and too high a heat avoided, this smell increases and becomes more delicate; and after the fermentation is completed, an oily azotised volatile matter, called *nicotine*, is found in the leaves. This substance—nicotine, which possesses all the properties of a base, was not present before the fermentation. The different kinds of tobacco are distinguished from one another, like wines, by having very different odoriferous substances, which are generated along with the nicotine.

We know that most of the blossoms and vegetable substances which possess a smell owe this property to a volatile oil existing in them; but it is not less certain that others emit a smell only when they undergo change or decomposition.

Arsenic and arsenious acid are both quite inodorous. It is only during their oxidation that they emit their characteristic odour of garlic. The oil of the berries of the elder-tree, many kinds of oil of turpentine, and oil of lemons, possess a smell only during their oxidation or decay. The same is the case with many blossoms; and Geiger has shown that the smell of musk is owing to its gradual putrefaction and decay.

It is also probable, that the peculiar odorous principle of many vegetable substances is newly formed during the fermentation of the saccharine juices of the plants. At all events, it is a fact, that very small quantities of the blossoms of the violet, elder, linden, or cowslip, added to a fermenting liquid, are sufficient to communicate a very strong taste and smell, which the addition of the water distilled from a quantity a hundred times greater would not effect. The various kinds of beer manufactured in

Bavaria are distinguished by different flavours, which are given by allowing small quantities of the herbs and blossoms of particular plants to ferment along with the wort. On the Rhine, also, an artificial *bouquet* is often given to wine for fraudulent purposes, by the addition of several species of the sage and rue to the fermenting liquor; but the fictitious perfume thus obtained differs from the genuine aroma, by its inferior durability, and by being gradually dissipated.

The juice of grapes grown in different climates differs not only in the proportion of free acid which it contains, but also in respect of the quantity of sugar dissolved in it. The quantity of azotised matter in the juice seems to be the same in whatever part the grapes may grow; at least no difference has been observed in the amount of yeast formed during fermentation in the south of France, and on the Rhine.

The grapes grown in hot climates, as well as the boiled juice obtained from them, are proportionally rich in sugar. Hence, during the fermentation of the juice, the complete decomposition of its azotised matters, and their separation in the insoluble state, are effected before all the sugar has been converted into alcohol and carbonic acid. A certain quantity of the sugar consequently remains mixed with the wine in an undecomposed state, the condition necessary for its further decomposition being absent.

The azotised matters in the juice of grapes of the temperate zones, on the contrary, are not completely separated in the insoluble state when the entire transformation of the sugar is effected. The wine of these grapes, therefore, does not contain sugar, but variable quantities of undecomposed gluten in solution.

This gluten gives the wine the property of becoming spontaneously converted into vinegar, when the access of air is not prevented.   For it absorbs oxygen and becomes insoluble ; and its oxidation is communicated to the alcohol, which is converted into acetic acid.

By allowing the wine to remain at rest in casks with a very limited access of air, and at the lowest possible temperature, the oxidation of this azotised matter is effected without the alcohol undergoing the same change, a higher temperature being necessary to enable alcohol to combine with oxygen.   As long as the wine in the *stilling-casks* deposits yeast, it can still be caused to ferment by the addition of sugar ; but old well-layed wine has lost this property, because the condition necessary for fermentation, namely, a substance in the act of decomposition or putrefaction, is no longer present in it.

In hotels and other places where wine is drawn gradually from a cask, and a proportional quantity of air necessarily introduced, its eremacausis, that is, its conversion into acetic acid, is prevented by the addition of a small quantity of sulphurous acid.   This acid, by entering into combination with the oxygen of the air contained in the cask, or dissolved in the wine, prevents the oxidation of the organic matter.

The various kinds of beer differ from one another in the same way as the wines.

English, French, and most of the German beers, are converted into vinegar when exposed to the action of air. But this property is not possessed by Bavarian beer, which may be kept in vessels only half-filled without acidifying or experiencing any change.   This valuable quality is obtained for it by a peculiar management of the fermentation of the wort.   The perfection of expe-

rimental knowledge has here led to the solution of one of the most beautiful problems of the theory of fermentation.

Wort is proportionally richer in gluten than in sugar; so that during its fermentation in the common way, a great quantity of yeast is formed as a thick scum. The carbonic acid evolved during the process attaches itself to the particles of the yeast, by which they become specifically lighter than the liquid in which they are formed, and rise to its surface. Gluten in the act of oxidation comes in contact with the particles of the decomposing sugar in the interior of the liquid. The carbonic acid from the sugar and insoluble ferment from the gluten are disengaged simultaneously, and cohere together.

A great quantity of gluten remains dissolved in the fermented liquid, even after the transformation of the sugar is completed, and this gluten causes the conversion of the alcohol into acetic acid, on account of its strong disposition to attract oxygen, and to undergo decay. Now, it is plain, that with its separation, and that of all substances capable of attracting oxygen, the beer would lose the property of becoming acid. This end is completely attained in the process of fermentation adopted in Bavaria.

The wort, after having been treated with hops in the usual manner, is thrown into very wide flat vessels, in which a large surface of the liquid is exposed to the air. The fermentation is then allowed to proceed, while the temperature of the chambers in which the vessels are placed is never allowed to rise above from 45° to 50° F. The fermentation lasts from three to six weeks, and the carbonic acid evolved during its continuance is not in large bubbles which burst upon the surface of the liquid,

but in small bubbles like those which escape from a liquid saturated by high pressure. The surface of the wort is scarcely covered with a scum, and all the yeast is deposited on the bottom of the vessel in the form of a viscous sediment.

In order to obtain a clear conception of the great difference between the two kinds of fermentation, it may perhaps be sufficient to recall to mind the fact, that the transformation of gluten or other azotised matters is a process consisting of several stages. The first stage is the conversion of the gluten into insoluble ferment in the interior of the liquid, and as the transformation of the sugar goes on at the same time, carbonic acid and yeast are simultaneously disengaged. It is known with certainty, that this formation of yeast depends upon oxygen being appropriated by the gluten in the act of decomposition; but it has not been sufficiently shown whether this oxygen is derived from the water, sugar, or from the gluten itself; whether it combines directly with the gluten, or merely with its hydrogen, so as to form water. For the purpose of obtaining a definite idea of the process, we may designate the first change as the stage of oxidation. This oxidation of the gluten, then, and the transposition of the atoms of the sugar into alcohol and carbonic acid, are necessarily attendant on each other; so that if the one is arrested, the other must also cease.

Now, the yeast which rises to the surface of the liquid is not the product of a complete decomposition, but is oxidised gluten still capable of undergoing a new transformation by the transposition of its constituent elements. By virtue of this condition it has the power to excite fermentation in a solution of sugar; and if the gluten be also present, the decomposing sugar induces its conver-

sion into fresh yeast, so that, in a certain sense, the yeast appears to reproduce itself.

Yeast of this kind is oxidised gluten in a state of *putrefaction*, and by virtue of this state it induces a similar transformation in the elements of the sugar.

The yeast formed during the fermentation of Bavarian beer is oxidised gluten in a state of *decay*. The process of decomposition which its constituents are suffering, gives rise to a very protracted putrefaction (*fermentation*) in the sugar. The intensity of the action is diminished in so great a degree, that the gluten which the fluid still holds in solution takes no part in it; the sugar in fermentation does not excite a similar state in the gluten.

But the contact of the already decaying and precipitated gluten or yeast, causes the eremacausis of the gluten dissolved in the wort; oxygen gas is absorbed from the air and all the gluten in solution is deposited as yeast.

The ordinary frothy yeast may be removed from fermenting beer by filtration, without the fermentation being thereby arrested ; but precipitated yeast of Bavarian beer cannot be removed without the whole process of its fermentation being interrupted. The beer ceases to ferment altogether, or, if the temperature is raised, undergoes the ordinary fermentation.

The precipitated yeast does not excite ordinary fermentation, and consequently is quite unfitted for the purpose of baking; but the common frothy yeast can cause the kind of fermentation by which the former kind of yeast is produced.

When common yeast is added to wort at a temperature of between 40° and 45° F., a slow tranquil fermentation takes place, and a matter is deposited on the bottom of the vessel, which may be employed to excite new fermen-

tation ; and when the same operation is repeated several
times in succession, the ordinary fermentation changes
into that process by which only precipitated yeast is
formed. The yeast now deposited has lost the property
of exciting ordinary fermentation, but it produces the
other process even at a temperature of 50° F.

In wort subjected to fermentation, at a low tempera-
ture, with this kind of yeast, the condition necessary for
the transformation of the sugar is the presence of that
yeast; but for the conversion of gluten into ferment by a
process of oxidation, something more is required.

When the power of gluten to attract oxygen is in-
creased by contact with precipitated yeast in a state of
decay, the unrestrained access of air is the only other
condition necessary for its own conversion into the same
state of decay, that is, for its oxidation. We have already
seen that the presence of free oxygen and gluten are con-
ditions which determine the eremacausis of alcohol and
its conversion into acetic acid, but they are incapable of
exerting this influence at low temperatures. A low tem-
perature retards the slow combustion of alcohol, while the
gluten combines spontaneously with the oxygen of the
air, just as sulphurous acid does when dissolved in water.
Alcohol undergoes no such change at low temperatures,
but during the oxidation of the gluten in contact with it, is
placed in the same condition as the gluten itself when sul-
phurous acid is added to the wine in which it is contained.
The oxygen of the air unites both with the gluten and
alcohol of wine not treated with sulphurous acid; but
when this acid is present it combines with neither of
them, being altogether absorbed by the acid. The same
thing happens in the peculiar process of fermentation
adopted in Bavaria. The oxygen of the air unites only

with the gluten and not with the alcohol, although it would have combined with both at higher temperatures, so as to form acetic acid.

Thus, then, this remarkable process of fermentation with the precipitation of a mucous-like ferment consists of a simultaneous putrefaction and decay in the same liquid. The sugar is in the state of putrefaction, and the gluten in that of decay.

Appert's method of preserving food, and this kind of fermentation of beer, depend on the same principle.

In the fermentation of beer after this manner, all the substances capable of decay are separated from it by means of an unrestrained access of air, while the temperature is kept sufficiently low to prevent the alcohol from combining with oxygen. The removal of these substances diminish the tendency of the beer to become acescent, or in other words, to suffer a further transformation.

In Appert's mode of preserving food, oxygen is allowed to enter into combination with the substance of the food, at a temperature at which decay, but neither putrefaction nor fermentation, can take place. With the subsequent exclusion of the oxygen and the completion of the decay, every cause which could effect further decomposition of the food is removed. The conditions for putrefaction are rendered insufficient in both cases; in the one by the removal of the substances susceptible of decay, in the other by the exclusion of the oxygen which would effect it.

It has been stated to be uncertain, whether gluten during its conversion into common yeast, that is, into the insoluble state in which it separates from fermenting liquids, really combines directly with oxygen. If it does combine with oxygen, then the difference between gluten and ferment would be, that the latter would

contain a larger proportion of oxygen. Now it is very
difficult to ascertain this, and even their analyses cannot
decide the question. Let us consider, for example, the
relations of alloxan and alloxantin* to one another.
Both of these bodies contain the same elements as
gluten, although in different proportions. Now they
are known to be convertible into each other, by oxygen
being absorbed in the one case, and in the other ex-
tracted. Both are composed of absolutely the same
elements, in equal proportions; with the single excep-
tion, that alloxantin contains 1 equivalent of hydrogen
more than alloxan.

When alloxantin is treated with chlorine and nitric
acid, it is converted into alloxan—into a body, therefore,
which is alloxantin *minus* 1 equivalent of hydrogen. If
on the other hand a stream of sulphuretted hydrogen is
conducted through alloxan, sulphur is precipitated, and
alloxantin produced. It may be said, that in the first
case hydrogen is abstracted, in the other added. But it
would be quite as simple an explanation, if we considered
them as oxides of the same radical : the alloxan being
regarded as a combination of a body composed of $C^8 N^2$
$H^2 O^6$ with 2 equivalents of water, and alloxantin as
a combination of 3 atoms of water, with a compound
consisting of $C^8 N^2 H^2 O^7$. The conversion of alloxan
into alloxantin would in this case result from its eight
atoms of oxygen being reduced to seven, while alloxan
would be formed out of alloxantin, by its combining with
an additional atom of oxygen.

Now, oxides are known which combine with water,
and present the same phenomena as alloxan and allox-
antin. But no compounds of hydrogen are known which

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* Compounds obtained by the action of nitric acid on uric acid.

form hydrates; and custom, which rejects all dissimilarity until the claim to peculiarity is quite proved, leads us to prefer an opinion, for which there is no further foundation than that of analogy. The woad (*Isatis tinctoria*) and several species of the *Nerium* contain a substance similar in many respects to gluten, which is deposited as indigo blue, when an aqueous infusion of the dried leaves is exposed to the action of the air. Now it is very doubtful whether the blue insoluble indigo is an oxide of the colourless soluble indigo, or the latter a combination of hydrogen with the indigo blue. Dumas has found the same elements in both, except that the soluble compound contained 1 equivalent of hydrogen more than the blue.

In the same manner, the soluble gluten may be considered a compound of hydrogen, which becomes ferment by losing a certain quantity of this element when exposed to the action of the oxygen of the air under favourable circumstances. At all events, it is certain that oxygen is the cause of the insoluble condition of gluten; for yeast is not deposited on keeping wine, or during the fermentation of Bavarian beer, unless oxygen has access to the fluid.

Now whatever be the form in which the oxygen unites with the gluten—whether it combines directly with it or extracts a portion of its hydrogen, forming water—the products formed in the interior of the liquid, in consequence of the conversion of the gluten into ferment, will still be the same. Let us suppose that gluten is a compound of. another substance with hydrogen, then this hydrogen must be removed during the ordinary fermentation of must and wort, by combining with oxygen,

exactly as in the conversion of alcohol into aldehyde by eremacausis.

In both cases the atmosphere is excluded; the oxygen cannot, then, be derived from the air, neither can it be supplied by the elements of water, for it is impossible to suppose that the oxygen will separate from the hydrogen of water, for the purpose of uniting with the hydrogen of gluten, in order again to form water. The oxygen must, therefore, be obtained from the elements of sugar, a portion of which substance must, in order to the formation of ferment, undergo a different decomposition from that which produces alcohol. Hence a certain part of the sugar will not be converted into carbonic acid and alcohol, but will yield other products containing less oxygen than sugar itself contains. These products, as has already been mentioned, are the cause of the great difference in the qualities of fermented liquids, and particularly in the quantity of alcohol which they contain.

Must and wort do not, therefore, in ordinary fermentation, yield alcohol in proportion to the quantity of sugar which they hold in solution, a part of the sugar being employed in the conversion of gluten into ferment, and not in the formation of alcohol. But in the fermentation of Bavarian beer all the sugar is expended in the production of alcohol; and this is especially the case whenever the transformation of the sugar is not accompanied by the formation of yeast.

It is quite certain that in the distilleries of brandy from potatoes, where no yeast is formed, or only a quantity corresponding to the malt which has been added, the proportion of alcohol and carbonic acid obtained during

the fermentation of the *mash* corresponds exactly to that of the carbon contained in the starch. It is also known that the volume of carbonic acid evolved during the fermentation of beet-roots gives no exact indication of the proportion of sugar contained in them, for less carbonic acid is obtained than the same quantity of pure sugar would yield.

Beer obtained by the mode of fermentation adopted in Bavaria contains more alcohol, and possesses more intoxicating properties, than that made by the ordinary method of fermentation, when the quantities of malt used are the same. The strong taste of the former beer is generally ascribed to its containing carbonic acid in larger quantity, and in a state of more intimate combination; but this opinion is erroneous. Both kinds of beer are, at the conclusion of the fermentation, completely saturated with carbonic acid, the one as much as the other. Like all other liquids, they both must retain such a portion of the carbonic acid evolved as corresponds to their power of solution, that is, to their volumes.

The temperature of the fluid during fermentation has a very important influence on the quantity of alcohol generated. It has been mentioned, that the juice of beet-roots allowed to ferment at from 86° to 95° (30° to 35° C.) yields no alcohol; and that afterwards, in the place of the sugar, mannite, a substance incapable of fermentation, and containing very little oxygen, is found, together with lactic acid and mucilage. The formation of these products diminishes in proportion as the temperature is lower. But in vegetable juices, containing nitrogen, it is impossible to fix a limit, where the transformation of the sugar is undisturbed by any other process of decomposition.

It is known that in the fermentation of Bavarian beer the action of the oxygen of the air, and the low temperature, cause *complete* transformation of the sugar into alcohol; the cause which would prevent that result, namely, the extraction of the oxygen of part of the sugar by the gluten, in its conversion into ferment, being avoided by the introduction of oxygen from without.

The quantity of matters in the act of transformation is naturally greatest at the beginning of the fermentation of must and wort; and all the phenomena which accompany the process, such as evolution of gas, and heat, are best observed at that time. These signs of the changes proceeding in the fluid diminish when the greater part of the sugar has undergone decomposition; but they must cease entirely before the process can be regarded as completed.

The less rapid process of decomposition which succeeds the violent evolution of gas, continues in wine and beer until the sugar has completely disappeared; and hence it is observed, that the specific gravity of the liquid diminishes during many months. This slow fermentation, in most cases, resembles the fermentation of Bavarian beer, the transformation of the dissolved sugar being in part the result of a slow and continued decomposition of the precipitated yeast; but a complete separation of the azotised substances dissolved in it cannot take place when air is excluded.*

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* The great influence which a rational management of fermentation exercises upon the quality of beer is well known in several of the German states. In the grand-duchy of Hesse, for example, a considerable premium is offered for the preparation of beer, according to the Bavarian method; and the premium is to be adjudged to any one who can prove that the beer brewed by him has laid for six months in the *store-vats*

Neither alcohol alone, nor hops, nor indeed both together, preserve beer from becoming acid. The better kinds of ale and porter in England are protected from acidity, but at the loss of the interest of an immense capital. They are placed in large closed wooden vessels, the surfaces of which are covered with sand. In these they are allowed to lie for several years, so that they are treated in a manner exactly similar to wine during its *ripening*.

A gentle diffusion of air takes place through the pores of the wood, but the quantity of azotised substances being very great in proportion to the oxygen which enters, they consume it, and prevent its union with the alcohol. But the beer treated in this way does not keep for two months without acidifying, if it be placed in smaller vessels, to which free access of the air is permitted.

without becoming acid. Hundreds of casks of beer became changed to vinegar before an empirical knowledge of those conditions was obtained, the influence of which is rendered intelligible by the theory.

CHAPTER X.

DECAY OF WOODY FIBRE.

THE conversion of woody fibre into the substances termed humus and mould is, on account of its influence on vegetation, one of the most remarkable processes of decomposition which occur in nature.

Decay is not less important in another point of view ; for, by means of its influence on dead vegetable matter, the oxygen which plants retained during life is again restored to the atmosphere.

The decomposition of woody fibre is effected in three forms, the results of which are different, so that it is necessary to consider each separately.

The first takes place when it is in the moist condition, and subject to free uninterrupted access of air ; the second occurs when the air is excluded ; and the third when the wood is covered with water, and in contact with putrefying organic matter.

It is known that woody fibre may be kept under water, or in dry air, for thousands of years without suffering any appreciable change ; but that when brought into contact with air, in the moist condition it converts the oxygen surrounding it into the same volume of carbonic acid, and is itself gradually changed into a yellowish brown, or black matter, of a loose texture *.

* According to the experiments of De Saussure, 240 parts of dry saw-dust of oak wood convert 10 cubic inches of oxygen into the same quan-

It has already been mentioned, that pure woody fibre contains carbon and the elements of water. Humus, however, is not produced by the decay of pure woody fibre, but by that of wood which contains foreign soluble and insoluble organic substances, besides its essential constituents.

The relative proportion of the component elements are, on this account, different in oak wood and in beech, and the composition of both of these differs very much from woody fibre, which is the same in all vegetables. The difference, however, is so trivial, that it may be altogether neglected in the consideration of the questions which will now be brought under discussion; besides, the quantity of the foreign substances is not constant, but varies according to the season of the year.

According to the careful analysis of Gay-Lussac and Thénard, 100 parts of oak wood, dried at 212° (100° C.), from which all soluble substances had been extracted by means of water and alcohol, contained 52·58 parts of carbon, and 47·47 parts of hydrogen and oxygen, in the same proportion as they are contained in water.

Now it has been mentioned that moist wood acts in oxygen gas exactly as if its carbon combined directly with oxygen, and that the products of this action are carbonic acid and humus.

If the action of the oxygen were confined to the carbon of the wood, and if nothing but carbon were removed from it, the remaining elements would necessarily be found in the humus, unchanged except in the particular of being combined with less carbon. The final result of

tity of carbonic acid, which contains 3 parts, by weight, of carbon; while the weight of the sawdust is diminished by 15 parts. Hence, 12 parts, by weight, of water, are at the same time separated from the elements of the wood.

the action would therefore be a complete disappearance
of the carbon, whilst nothing but the elements of water
would remain.

But when decaying wood is subjected to examination
in different stages of its decay, the remarkable result is
obtained, that the proportion of carbon in the different
products augments. Consequently, if we did not take
into consideration the evolution of carbonic acid under
the influence of the air, the conversion of wood into
humus might be viewed as a removal of the elements of
water from the carbon.

The analysis of mouldered oak wood, which was taken
from the interior of the trunk of an oak, and possessed a
chocolate brown colour and the structure of wood, showed
that 100 parts of it contained 53·36 parts of carbon and
46·44 parts of hydrogen and oxygen in the same relative
proportions as in water. From an examination of
mouldered wood of a light-brown colour, easily reducible
to a fine powder, and taken from another oak, it appeared
that it contained 56·211 carbon and 43·789 water.

These indisputable facts point out the similarity of the
decay of wood, with the slow combustion or oxidation of
bodies which contain a large quantity of hydrogen.
Viewed 'as a kind of combustion, it would indeed be a
very extraordinary process, if the carbon combined di-
rectly with the oxygen; for it would be a combustion in
which the carbon of the burning body augmented con-
stantly, instead of diminishing. Hence it is evident that
it is the hydrogen which is oxidised at the expense of
the oxygen of the air; while the carbonic acid is formed
from the elements of the wood. Carbon never combines
at common temperatures with oxygen, so as to form
carbonic acid.

In whatever stage of decay wood may be, its elements must always be capable of being represented by their equivalent numbers.

The following formula illustrates this fact with great clearness:

C36 H22 O22—oak wood, according to Gay-Lussac and Thénard.*
C35 H20 O20—humus from oak wood (Meyer).†
C34 H18 O18—   „   „   (Dr. Will).‡

It is evident from these numbers that for every two equivalents of hydrogen which are oxidised, two atoms of oxygen and one of carbon are set free.

Under ordinary circumstances, woody fibre requires a very long time for its decay; but this process is of course much accelerated by an elevated temperature and free, unrestrained access of air. The decay, on the contrary, is much retarded by absence of moisture, and by the wood being surrounded with an atmosphere of carbonic acid, which prevents the access of air to the decaying matters.

Sulphurous acid, and all antiseptic substances, arrest the decay of woody fibre. It is well known that corrosive sublimate is employed for the purpose of protecting the timber of ships from decay; it is a substance which completely deprives vegetable or animal matters, the most prone to decomposition, of their property of entering into fermentation, putrefaction, or decay.

But the decay of woody fibre is very much accelerated by contact with alkalies or alkaline earths; for these enable substances to absorb oxygen, which do not possess this power themselves; alcohol, gallic acid, tannin, the vegetable colouring matters, and several other substances,

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* The calculation gives 52·5 carbon, and 47·5 water.
† The calculation gives 54.carbon, and 46 water.
‡ The calculation gives 56 carbon, and 44 water.

are thus affected by them. Acids produce quite an opposite effect; they greatly retard decay.

Heavy soils, consisting of loam, retain longest the most important condition for the decay of the vegetable matter contained in them, viz., water; but their impermeable nature prevents contact with the air.

In moist sandy soils, particularly such as are composed of a mixture of sand and carbonate of lime, decay proceeds very quickly, it being aided by the presence of the slightly alkaline lime.

Now let us consider the decay of woody fibre during a very long period of time, and suppose that its cause is the gradual removal of the hydrogen in the form of water, and the separation of its oxygen in that of carbonic acid. It is evident that if we subtract from the formula C^{36}, H^{22}, O^{22}, the 22 equivalents of oxygen, with 11 equivalents of carbon, and 22 equivalents of hydrogen, which are supposed to be oxidised by the oxygen of the air, and separated in the form of water; then, from 1 atom of oak wood, 25 atoms of pure carbon will remain as the final product of the decay. In other words, 100 parts of oak, which contain 52·5 parts of carbon, will leave as a residue 37 parts of carbon, which must remain unchanged, since carbon does not combine with oxygen at common temperatures.

But 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.

In proportion as the decay of woody fibre advances, its property of burning with flame, or, in other words, of developing carburetted hydrogen on the application of heat, diminishes. Decayed wood burns without flame; whence no other conclusion can be drawn, than that the hydrogen, which analysis shows to be present, is not contained in it in the same form as in wood.

Decayed oak contains more carbon than fresh wood, but its hydrogen and oxygen are in the same proportion.

We would naturally expect that the flame given out by decayed wood should be more brilliant in proportion to the increase of its carbon; but we find, on the contrary, that it burns like tinder, exactly as if no hydrogen were present. For the purposes of fuel, decayed or diseased wood is of little value, for it does not possess the property of burning with flame, a property upon which the advantages of common wood depend. The hydrogen of decayed wood must consequently be supposed to be in the state of water; for had it any other form, the characters we have described would not be possessed by the decayed wood.

If we suppose decay to proceed in a liquid which contains both carbon and hydrogen, then a compound containing still more carbon must be formed, in a manner similar to the production of the crystalline colourless naphthalin, from a gaseous compound of carbon and hydrogen. And if the compound thus formed were itself to undergo further decay, the final result must be the separation of carbon in a crystalline form.

Science can point to no process capable of accounting for the origin and formation of diamonds, except the process of decay. Diamonds cannot be produced by the action of fire, for a high temperature and the presence

of oxygen gas would call into play their combustibility. But there is the greatest reason to believe that they are formed in the humid way, that is, in a liquid; and the process of decay is the only cause to which their formation can with probability be ascribed.

Amber, fossil resin, and the acids in mellite, are the products of vegetable matter which has suffered decomposition. They are found in wood or brown coal, and have evidently proceeded from the decomposition of substances which were contained in quite a different form in the living plants. They are all distinguished by the proportionally small quantity of hydrogen which they contain. The acid from mellite (mellitic acid) contains precisely the same proportions of carbon and oxygen as that from amber (succinic acid); they differ only in the proportion of their hydrogen. M. Bromeis * found that *succinic acid might be artificially formed by the action of nitric acid on stearic acid*, a true process of eremacausis; the experiment was made in this laboratory (Giessen).

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* Liebig's Annalen, Band xxxiv., heft 3.

CHAPTER XI.

VEGETABLE MOULD.

The term *vegetable mould,* in its general signification, is applied to a mixture of disintegrated minerals, with the remains of animal and vegetable substances. It may be considered as earth in which humus is contained in a state of decomposition. Its action upon the air has been fully investigated by Ingenhouss and De Saussure.

When moist vegetable mould is placed in a vessel full of air, it extracts the oxygen therefrom with greater rapidity than decayed wood, and replaces it by an equal volume of carbonic acid. When this carbonic acid is removed and fresh air admitted, the same action is repeated.

Cold water dissolves only $\frac{1}{10,000}$th of its own weight of vegetable mould; and the residue left on its evaporation consists of common salt with traces of sulphate of potash and lime, and a minute quantity of organic matter, for it is blackened when heated to redness. Boiling water extracts several substances from vegetable mould, and acquires a yellow or yellowish brown colour, which is dissipated by absorption of oxygen from the air, a black flocculent deposit being formed. When the coloured solution is evaporated, a residue is left, which becomes black on being heated to redness, and afterwards yields carbonate of potash when treated with water.

A solution of caustic potash becomes black when placed in contact with vegetable mould, and the addition of acetic acid to the coloured solution causes no precipitate or turbidity. But dilute sulphuric acid throws down a light flocculent precipitate of a brown or black colour, from which the acid can be removed with difficulty by means of water. When this precipitate, after having been washed with water, is brought whilst still moist under a receiver filled with oxygen, the gas is absorbed with great rapidity; and the same thing takes place when the precipitate is dried in the air. In the perfectly dry state it has entirely lost its solubility in water, and even alkalies dissolve only traces of it.

It is evident, therefore, that boiling water extracts a matter from vegetable mould, which owes its solubility to the presence of the alkaline salts contained in the remains of plants. *This substance is a product of the incomplete decay of woody fibre. Its composition is intermediate between woody fibre and humus, into which it is converted by being exposed in a moist condition to the action of the air.*

CHAPTER XII.

THE decomposition of wood, woody fibre, and all vegetable bodies when subjected to the action of water, and excluded from the air, is termed *mouldering*.

Wood, or brown coal, and mineral coal, are the remains of vegetables of a former world; their appearance and characters show that they are products of the processes of decomposition termed decay and putrefaction. We can easily ascertain by analysis the manner in which their constituents have been changed, if we suppose the greater part of their bulk to have been formed from woody fibre.

But it is necessary, before we can obtain a distinct idea of the manner in which coal is formed, to consider a peculiar change which woody fibre suffers by means of moisture, when partially or entirely excluded from the air.

It is known, that when pure woody fibre, as linen, for example, is placed in contact with water, considerable heat is evolved, and the substance is converted into a soft friable mass which has lost all coherence. This substance was employed in the fabrication of paper before the use of chlorine, as an agent for bleaching. The rags employed for this purpose were placed in heaps, and it was observed, that on their becoming warm a gas was disengaged, and their weight diminished from 18. to 25 per cent.

When sawdust moistened with water is placed in a closed vessel, carbonic acid gas is evolved in the same manner as when air is admitted. A true putrefaction takes place; the wood assumes a white colour, loses its peculiar texture, and is converted into a rotten friable matter.

The white decayed wood found in the interior of trunks of dead trees which have been in contact with water, is produced in the way just mentioned.

An analysis of wood of this kind, obtained from the interior of the trunk of an oak, yielded, after having been dried at 212°,

Carbon	47·11	.	.	48·14
Hydrogen	6·31	.	.	6·06
Oxygen	45·31	.	.	44·46
Ashes	1·27	.	.	1·37
	100·00			100·00

Now, on comparing the proportions obtained from these numbers with the composition of oak wood, according to the analysis of Gay-Lussac and Thénard, it is immediately perceived that a certain quantity of carbon has been separated from the constituents of wood, whilst the hydrogen is, on the contrary, increased. The numbers obtained by the analysis correspond very nearly to the formula $C33 \ H27 \ O24$.*

The elements of water have, therefore, become united with the wood, whilst carbonic acid is disengaged by the absorption of a certain quantity of oxygen.

If the elements of 5 atoms of water and 8 atoms of oxygen be added to the composition of the woody fibre

* The calculation from this formula gives in 100 parts 47·9 carbon, 6·1 hydrogen, and 46 oxygen.

of the oak, and 3 atoms of carbonic acid deducted, the
exact formula for white mouldered wood is obtained.

Wood	C36 H22 O22
To this add 5 atoms of water	H 5 O 5
3 atoms of oxygen	O 3
	C36 H27 O30
Subtract from this 3 atoms Carbonic acid	C 3 O 6
	C33 H27 O24

The process of mouldering is, therefore, one of putre-
faction and decay, proceeding simultaneously, in which
the oxygen of the air and the component parts of water
take part. But the composition of mouldered wood must
change according as the access of oxygen is more or less
prevented. White mouldered beech-wood yielded on
analysis 47·67 carbon, 5·67 hydrogen, and 46 68 oxygen ;
this corresponds to the formula C33 H25 O24.

The decomposition of wood assumes, therefore, two
different forms, according as the access of the air is free
or restrained. In both cases carbonic acid is generated ;
and in the latter case, a certain quantity of water enters
into chemical combination.

It is highly probable that in this putrefactive process,
as well as in all others, the oxygen of the water assists in
the formation of the carbonic acid.

Wood coal (brown coal of Werner) must have been
produced by a process of decomposition similar to that
of mouldering. But it is not easy to obtain wood coal
suited for analysis, for it is generally impregnated with
resinous or earthy substances, by which the composition
of those parts which have been formed from woody fibre
is essentially changed.

The wood coal, which forms extensive layers in the
Wetterau (a district in Hesse Darmstadt), is distinguished

from that found in other places, by possessing the struc-
ture of wood unchanged, and by containing no bitu-
minous matter. This coal was subjected to analysis, a.
piece being selected upon which the annual circle could
be counted. It was obtained from the vicinity of Lau-
bach; 100 parts contained

Carbon	.	.	.	.	.	.	57·28
Hydrogen	.	.	.	.	.	.	6·03
Oxygen	.	.	.	.	.	.	36·10
Ashes	.	.	.	.	.	.	0·59
							100·00

The large amount of carbon, and small quantity of
oxygen, constitute the most obvious difference between
this analysis and that of wood. It is evident that the
wood which has undergone the change into coal must
have parted with a certain portion of its oxygen. The
proportions of these numbers are expressed by the for-
mula C33 H21 O16*.

When these numbers are compared with those ob-
tained by the analysis of oak, it would appear that the
brown coal was produced from woody fibre by the sepa-
ration of one equivalent of hydrogen, and the elements
of three equivalents of carbonic acid.

1 atom wood C36 H22 O22
Minus 1 atom hydrogen and 3 atoms car- } C 3 H 1 O 6
bonic acid . . . . . . }

WOOD COAL . . C33 H21 O16

All varieties of wood coal, from whatever strata they
may be taken, contain more hydrogen than wood does,
and less oxygen than is necessary to form water with
this hydrogen; consequently they must all be produced

* The calculation gives 57·5 carbon, and 5·98 hydrogen.

by the same process of decomposition. The excess of hydrogen is either hydrogen of the wood which has remained in it unchanged, or it is derived from some exterior source. The analysis of wood coal from Ring-kuhl, near Cassel, where it is seldom found in pieces with the structure of wood, gave, when dried at 212°,

Carbon	62·60	.	.	63·83
Hydrogen	5·02	.	.	4·80
Oxygen	26·52	.	.	25·51
Ashes	5·86	.	.	5·86
	100·00			100·00

The proportions derived from these numbers correspond very closely to the formula $C^{32} H^{15} O^{9}$, or they represent the constituents of wood, from which the elements of carbonic acid, water, and 2 equivalents hydrogen, have been separated.

C36 H22 O22=Wood.
Subtract C 4 H 7 O13=4 atoms carbonic acid+5 atoms of water
+2 atoms of hydrogen.

C32 H15 O 9=Wood Coal from Ringkuhl.

The formation of both these specimens of wood coal appears from these formulæ to have taken place under circumstances which did not entirely exclude the action of the air, and consequent oxidation and removal of a certain quantity of hydrogen. Now the Laubacher coal is covered with a layer of basalt, and the coal of Ring-kuhl was taken from the lowest seam of layers, which possess a thickness of from 90 to 120 feet; so that both may be considered as well protected from the air.

During the formation of brown coal, the elements of carbonic acid have been separated from the wood either alone, or at the same time with a certain quantity of

water. It is quite possible that the difference in the process of decomposition may depend upon the high temperature and pressure under which the decomposition took place. At least, a piece of wood assumed the character and appearance of Laubacher coal, after being kept for several weeks in the boiler of a steam-engine, and had then precisely the same composition. The change in this case was effected in water, at a temperature of from 334° to 352° F. (150°—160° C.), and under a corresponding pressure. The ashes of the wood amounted to 0·51 per cent.; a little less, therefore, than those of the Laubacher coal; but this must be ascribed to the peculiar circumstances under which it was formed. The ashes of plants examined by Berthier amounted always to much more than this.

The peculiar process by which the decomposition of these extinct vegetables has been effected, namely, a disengagement of carbonic acid from their substance, appears still to go on at great depths in all the layers of wood coal. At all events, it is remarkable that springs impregnated with carbonic acid occur in many places, in the country between Meissner, in the electorate of Hesse, and the Eifel, which are known to possess large layers of wood coal. These springs of mineral water are produced on the spot at which they are found; the springs of common water meeting with carbonic acid during their ascent, and becoming impregnated with it.

In the vicinity of the layers of wood coal at Salshausen (Hesse Darmstadt) an excellent acidulous spring of this kind existed a few years ago, and supplied all the inhabitants of that district; but it was considered advantageous to surround the sides of the spring with sandstone, and the consequence was, that all the outlets to the

carbonic acid were closed, for this gas generally gains
access to the water from the sides of the spring. From
that time to the present this valuable mineral water has
disappeared, and in its place is found a spring of com-
mon water.

Springs of water impregnated with carbonic acid occur
at Schwalheim, at a very short distance from the layers
of wood coal at Dorheim. M. Wilhelmi observed some
time since, that they are formed of common spring water
which ascends from below, and of carbonic acid which
issues from the sides of the spring. The same fact has
been shown to be the case in the famed Fachinger spring,
by M. Schapper.

The carbonic acid gas from the springs in the Eifel is,
according to Bischoff, seldom mixed with nitrogen or
oxygen, and is probably produced in a manner similar to
that just described. At any rate, the air does not appear
to take any part in the formation of these acidulous
springs. Their carbonic acid has evidently not been
formed either by a combustion at high or low tempera-
tures ; for if it were so, the gas resulting from the com-
bustion would necessarily be mixed with $\frac{4}{5}$ of nitrogen,
but it does not contain a trace of this element. The
bubbles of gas which escape from these springs are
absorbed by caustic potash, with the exception of a resi-
duum too small to be appreciated.

The wood coal of Dorheim and Salzhausen must have
been formed in the same way as that of the neighbouring
village of Laubach ; and since the latter contains the
exact elements of woody fibre, minus a certain quantity
of carbonic acid, its composition indicates very plainly
the manner in which it has been produced.

The coal of the upper bed is subjected to an incessant

decay by the action of the air, by means of which its
hydrogen is removed in the same manner as in the decay
of wood. This is recognised by the way in which it
burns, and by the formation of carbonic acid in the
mines.

The gases which are formed in mines of wood coal,
and cause danger in their working, are not combustible
or inflammable, as in mines of mineral coal; but they con-
sist generally of carbonic acid gas, and are very seldom
intermixed with combustible gases.

Wood coal from the middle bed of the strata at Ring-
kuhl gave on analysis 65·40—64·01 carbon and 4·75—
4·76* hydrogen; the proportion of carbon here is the
same as in specimens procured from greater depths, but
that of the hydrogen is much less.

Wood and mineral coal are always accompanied by
iron pyrites (sulphuret of iron) or zinc blende (sulphuret
of zinc); which minerals are still formed from salts of
sulphuric acid, with iron or zinc, during the putrefaction
of all vegetable matter. It is possible that the oxygen
of the sulphates in the layers of wood coal is the means
by which the removal of the hydrogen is effected, since
wood coal contains less of this element than wood.

According to the analysis of Richardson and Regnault,
the composition of the combustible materials in splint
coal from Newcastle, and cannel coal from Lancashire, is
expressed by the formula $C24 \ H13 \ O$. When this is
compared with the composition of woody fibre, it appears
that these coals are formed from its elements, by the
removal of a certain quantity of carburetted hydrogen and

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* The analysis of brown coal from Ringkuhl, as well as all those of
the same substance given in this work, have been executed in this labo-
ratory by M. Kühnert of Cassel.

carbonic acid in the form of combustible oils. The composition of both of these coals is obtained by the subtraction of 3 atoms of carburetted hydrogen, 3 atoms of water, and 9 atoms of carbonic acid from the formula of wood.

	$C36$ $H22$ $O22$=wood
3 atoms of carburetted hydrogen $C3$ $H6$	
3 atoms of water . . $H3$ $O3$	
9 atoms of carbonic acid $C9$ $O18$	$C12$ H 9 $O21$
Mineral coal	$C24$ $H13$ O

Carburetted hydrogen generally accompanies all mineral coal ; other varieties of coal contain volatile oils which may be separated by distillation with water. (Reichenbach.) The origin of naphtha is owing to a similar process of decomposition. Caking coal from Caresfield, near Newcastle, contains the elements of cannel coal, *minus* the constituents of olefiant gas $C4$ $H4$.

The inflammable gases which stream out of clefts in the strata of mineral coal, or in rocks of the coal formations, always contain carbonic acid, according to a recent examination by Bischoff, and also carburetted hydrogen, nitrogen, and olefiant gas ; the last of which had not been observed, until *its existence in these gases was pointed out by Bischoff.* The analysis of *fire-damp* after it had been treated with caustic potash, showed its constituents to be—

	Gas from an abandoned mine near Wallesweiler.	Gerbard's passage near Lu-isenthal.	Gas from a mine near Liekwege.
	Vol.	Vol.	Vol.
Light carburetted hydrogen	91·36	83·08	79·10
Olefiant gas .	6·32	1·98	16·11
Nitrogen gas .	2·32	14·94	4·79
	100·00	100·00	100·00

The evolution of these gases proves that changes are constantly proceeding in the coal.

It is obvious from this, that a continual removal of oxygen in the form of carbonic acid is effected from layers of wood coal, in consequence of which the wood must approach gradually to the composition of mineral coal. Hydrogen, on the contrary, is disengaged from the constituents of mineral coal in the form of a compound of carbo-hydrogen ; a complete removal of all the hydrogen would convert coal into anthracite.

The formula $C36\ H22\ O22$, which is given for wood, has been chosen as the empirical expression of the analysis, for the purpose of bringing all the transformations which woody fibre is capable of undergoing under one common point of view.

Now, although the correctness of this formula must be doubted, until we know with certainty the true constitution of woody fibre, this cannot have the smallest influence on the account given of the changes to which woody fibre must necessarily be subjected in order to be converted into wood or mineral coal. The theoretical expression refers to the quantity, the empirical merely to the relative *proportion* in which the elements of a body are united. Whatever form the first may assume, the empirical expression must always remain unchanged.

CHAPTER XIII.

ON POISONS, CONTAGIONS, AND MIASMS.

A GREAT many chemical compounds, some derived from inorganic nature, and others formed in animals and plants, produce peculiar changes or diseases in the living animal organism. They destroy the vital functions of individual organs; and when their action attains a certain degree of intensity, death is the consequence.

The action of inorganic compounds, such as acids, alkalies, metallic oxides, and salts, can in most cases be easily explained. They either destroy the continuity of particular organs, or they enter into combination with their substance. The action of sulphuric, muriatic, and oxalic acids, hydrate of potash, and all those substances which produce the direct destruction of the organs with which they come into contact, may be compared to a piece of iron, which can cause death by inflicting an injury on particular organs, either when heated to redness, or when in the form of a sharp knife. Such substances are not poisons in the limited sense of the word, for their injurious action depends merely upon their condition.

The action of the proper inorganic poisons is owing, in most cases, to the formation of a chemical compound by the union of the poison with the constituents of the organ upon which it acts; it is owing to an exercise of

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a chemical affinity more powerful than the vitality of the organ.

It is well to consider the action of inorganic substances in general, in order to obtain a clear conception of the mode of action of those which are poisonous. We find that certain soluble compounds, when presented to different parts of the body, are absorbed by the blood, whence they are again eliminated by the organs of secretion, either in a changed or in an unchanged state.

Iodide of potassium, sulpho-cyanuret of potassium, ferro-cyanuret of potassium, chlorate of potash, silicate of potash, and all salts with alkaline bases, when administered internally to man and animals in dilute solutions, or applied externally, may be again detected in the blood, sweat, chyle, gall, and splenic veins; but all of them are finally excreted from the body through the urinary passages.

Each of these substances, in its transit, produces a peculiar disturbance in the organism—in other words, they exercise a medicinal action upon it, but they themselves suffer no decomposition. If any of these substances enter into combination with any part of the body, the union cannot be of a permanent kind; for their reappearance in the urine shows that any compounds thus formed must have been again decomposed by the vital processes.

Neutral citrates, acetates, and tartrates of the alkalies suffer change in their passage through the organism. Their bases can indeed be detected in the urine, but the acids have entirely disappeared, and are replaced by carbonic acid which has united with the bases. (Gilbert Blane and Wöhler.)

The conversion of these salts of organic acids into

carbonates, indicates that a considerable quantity of oxygen must have united with their elements. In order to convert 1 equivalent of acetate of potash into the carbonate of the same base, 8 equivalents of oxygen must combine with it, of which either 2 or 4 equivalents (according as an acid or neutral salt is produced) remain in combination with the alkali; whilst the remaining 6 or 4 equivalents are disengaged as free carbonic acid. There is no evidence presented by the organism itself, to which these salts have been administered, that any of its proper constituents have yielded so great a quantity of oxygen as is necessary for their conversion into carbonates. Their oxidation can, therefore, only be ascribed to the oxygen of the air.

During the passage of these salts through the lungs, their acids take part in the peculiar process of eremacausis which proceeds in that organ ; a certain quantity of the oxygen gas inspired unites with their constituents, and converts their hydrogen into water, and their carbon into carbonic acid. Part of this latter product (1 or 2 equivalents) remains in combination with the alkaline base, forming a salt which suffers no further change by the process of oxidation ; and it is this salt which is separated by the kidneys or liver.

It is manifest that the presence of these organic salts in the blood must produce a change in the process of respiration. A part of the oxygen inspired, which usually combines with the constituents of the blood, must when they are present, combine with their acids, and thus be prevented from performing its usual office. The immediate consequence of this must be the formation of arterial blood in less quantity, or in other words, the process of respiration must be retarded.

Neutral acetates, tartrates, and citrates placed in contact with the air, and at the same time with animal or vegetable bodies in a state of eremacausis, produce exactly the same effects as we have described them to produce in the lungs. They participate in the process of decay, and are converted into carbonates just as in the living body. If impure solutions of these salts in water are left exposed to the air for any length of time, their acids are gradually decomposed, and at length entirely disappear.

Free mineral acids, or organic acids which are not volatile, and salts of mineral acids with alkaline bases, completely arrest decay when added to decaying matter in sufficient quantity ; and when their quantity is small, the process of decay is protracted and retarded. They produce in living bodies the same phenomena as the neutral organic salts, but their action depends upon a different cause.

The absorption by the blood of a quantity of an inorganic salt sufficient to arrest the process of eremacausis in the lungs, is prevented by a very remarkable property of all animal membranes, skin, cellular tissue, muscular fibre, &c.; namely, by their incapability of being permeated by concentrated saline solutions. It is only when these solutions are diluted to a certain degree with water that they are absorbed by animal tissues.

A dry bladder remains more or less dry in saturated solutions of common salt, nitre, ferro-cyanuret of potassium, sulpho-cyanuret of potassium, sulphate of magnesia, chloride of potassium, and sulphate of soda. These solutions run off its surface in the same manner as water runs from a plate of glass besmeared with tallow.

Fresh flesh, over which salt has been strewed, is found after 24 hours swimming in brine, although not a drop

of water has been added. The water has been yielded by muscular fibre itself, and having dissolved the salt in immediate contact with it, and thereby lost the power of penetrating animal substances, it has on this account separated from the flesh. The water still retained by the flesh contains a proportionally small quantity of salt, having that degree of dilution at which a saline fluid is capable of penetrating animal substances.

This property of animal tissues is taken advantage of in domestic economy for the purpose of removing so much water from meat that a sufficient quantity is not left to enable it to enter into putrefaction.

In respect of this physical property of animal tissues, alcohol resembles the inorganic salts. It is incapable of moistening, that is, of penetrating, animal tissues, and possesses such an affinity for water as to extract it from moist substances.

When a solution of a salt, in a certain degree of dilution, is introduced into the stomach, it is absorbed; but a concentrated saline solution, in place of being itself absorbed, extracts water from the organ, and a violent thirst ensues. Some interchange of water and salt takes place in the stomach ; the coats of this viscus yield water to the solution, a part of which having previously become sufficiently diluted, is, on the other hand, absorbed. But the greater part of the concentrated solution of salt remains unabsorbed, and is not removed by the urinary passages ; it consequently enters the intestines and intestinal canal, where it causes a dilution of the solid substances deposited there, and thus acts as a *purgative*.

Each of the salts just mentioned possesses this purgative action, which depends on a physical property shared by all of them ; but besides this they exercise a medicinal

If the poisoning is merely superficial, and the quantity
of the poison so small that only individual parts of
the body which are capable of being regenerated have
entered into combination with it, then eschars are pro-
duced—a phenomenon of a secondary kind—the com-
pounds of the dead tissues with the poison being thrown
off by the healthy parts. From these considerations it
may readily be inferred that all internal signs of poison-
ing are variable and uncertain; for cases may happen, in
which no apparent indication of change can be detected
by simple observations of the parts, because, as has been
already remarked, death may occur without the destruc-
tion of any organs.

When arsenious acid is administered in solution, it may
enter into the blood. If a vein is exposed and surrounded
with a solution of this acid, every blood-globule will com-
bine with it, that is, will become poisoned.

The compounds of arsenic, which have not the pro-
perty of entering into combination with the tissues of the
organism, *are without influence on life, even in large
doses. Many insoluble basic salts of arsenious acid are
known not to be poisonous. The substance called alkar-
gen, discovered by Bunsen, has not the slightest injurious
action upon the organism; yet it contains a very large
quantity of arsenic, and approaches very closely in com-
position to the organic arsenious compounds found in the
body.

These considerations enable us to fix with tolerable
certainty the limit at which the above substances cease
to act as poisons. For since their combination with
organic matters must be regulated by chemical laws,
death will inevitably result, when the organ in contact
with the poison finds sufficient of it to unite with, atom

for atom ; whilst if the poison is present in smaller quantity, a part of the organ will retain its vital functions.

According to the experiments of Mulder*, the equivalent in which fibrin combines with muriatic acid, and with the oxides of lead and copper, is expressed by the number 6361. It may be assumed therefore approximatively, that a quantity of fibrin corresponding to the number 6361 combines with 1 equivalent of arsenious acid, or 1 equivalent of corrosive sublimate.

When 6361 parts of anhydrous fibrin are combined with 30,000 parts of water, it is in the state in which it is contained in muscular fibre or blood in the human body. 100 grains of fibrin in this condition would form a neutral compound of equal equivalents with $3\frac{4}{10}$ grains of arsenious acid, and 5 grains of corrosive sublimate.

The atomic weight of the albumen of eggs and of the blood deduced from the analysis of the compound which it forms with oxide of silver is 7447, and that of animal gelatin 5652.

100 grains of albumen containing all the water with which it is combined in the living body, should consequently combine with $1\frac{}{4}$ grain of arsenious acid.

These proportions, which may be considered as the highest which can be adopted, indicate the remarkably high atomic weights of animal substances, and at the same time teach us what very small quantities of arsenious acid or corrosive sublimate are requisite to produce deadly effects.

All substances administered as antidotes in cases of poisoning act by destroying the power which arsenious acid and corrosive sublimate possess, of entering into combination with animal matters, and of thus acting as

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* Poggendorff's Annalen, Band xl. S. 259.

poisons. Unfortunately no other body surpasses them in that power, and the compounds which they form can only be broken up by affinities so energetic, that their action is as injurious as that of the above-named poisons themselves. The duty of the physician consists, therefore, in his causing those parts of the poison which may be free and still uncombined, to enter into combination with some other body, so as to produce a compound incapable of being decomposed or digested in the same conditions. Hydrated peroxide of iron is an invaluable substance for this purpose.

When the action of arsenious acid or corrosive sublimate is confined to the surface of an organ, those parts only are destroyed which enter into combination with it; an eschar is formed, which is gradually thrown off.

Soluble salts of silver would be quite as deadly a poison as corrosive sublimate, did not a cause exist in the human body by which their action is prevented, unless their quantity is very great. This cause is the presence of common salt in all animal liquids. Nitrate of silver, it is well known, combines with animal substances, in the same manner as corrosive sublimate, and the compounds formed by both are exactly similar in the character of being incapable of decay or putrefaction.

When nitrate of silver in a state of solution is applied to skin or muscular fibre, it combines with them instantaneously; animal substances dissolved in any liquid are precipitated by it, and rendered insoluble, or, as it is usually termed, they are coagulated. The compounds thus formed are colourless, and so stable, that they cannot be decomposed by other powerful chemical agents. They are blackened by exposure to light, like all other

compounds of silver, in consequence of a part of the oxide of silver which they contain being reduced to the metallic state. Parts of the body which have united with salts of silver no longer belong to the living organism, for their vital functions have been arrested by combination with oxide of silver; and if they are capable of being reproduced, the neighbouring living structures throw them off in the form of an eschar.

When nitrate of silver is introduced into the stomach, it meets with common salt and free muriatic acid; and if its quantity is not too great, it is immediately converted into chloride of silver—a substance which is absolutely insoluble in pure water. In a solution of salt or muriatic acid, however, chloride of silver does dissolve in extremely minute quantity; and it is this small part which exercises a medicinal influence when nitrate of silver is administered; the remaining chloride of silver is eliminated from the body in the ordinary way. Solubility is necessary to give efficacy to any substance in the human body.

The soluble salts of lead possess many properties in common with the salts of silver and mercury; but all compounds of lead with organic matters are capable of decomposition by dilute sulphuric acid. The disease called *painter's colic* is unknown in all manufactories of white-lead in which the workmen are accustomed to take as a preservative *sulphuric-acid-lemonade* (a solution of sugar rendered acid by sulphuric acid).

The organic substances which have combined in the living body with metallic oxides or metallic salts, lose their property of imbibing water and retaining it, without at the same time being rendered incapable of permitting

liquids to penetrate through their pores. A strong con-
traction and shrinking of the surface is the general effect
of contact with these metallic bodies. But corrosive sub-
limate, and several of the salts of lead, possess a peculiar
property, in addition to those already mentioned. When
they are present in excess, they dissolve the first formed
insoluble compounds, and thus produce an effect quite
the reverse of contraction, namely, a softening of the part
of the body on which they have acted.

Salts of oxide of copper, even when in combination
with the most powerful acids, are reduced by many vege-
table substances, particularly such as sugar and honey,
either into metallic copper, or into the red suboxide,
neither of which enters into combination with animal
matter. It is well known that sugar has been long
employed as the most convenient antidote for poisoning
by copper.

With respect to some other poisons, namely, hydro-
cyanic acid and the organic bases, *strychnia* and *brucia*, we
are acquainted with no facts calculated to elucidate the
nature of their action. It may, however, be presumed
with much certainty, that experiments upon their mode of
action on different animal substances would very quickly
lead to the most satisfactory conclusions regarding the
cause of their poisonous effects.

There is a peculiar class of substances, which are
generated during certain processes of decomposition, and
which act upon the animal economy as deadly poisons,
not on account of their power of entering into combina-
tion with it, or by reason of their containing a poisonous
material, but solely by virtue of their peculiar condition.

In order to attain to a clear conception of the mode of

action of these bodies, it is necessary to call to mind the cause on which we have shown the phenomena of fermentation, decay, and putrefaction to depend.

This cause may be expressed by the following law, long since proposed by La Place and Berthollet, although its truth with respect to chemical phenomena has only lately been proved. "*A molecule set in motion by any power can impart its own motion to another molecule with which it may be in contact.*"

This is a law of dynamics, the operation of which is manifest in all cases, in which the resistance *(force, affinity, or cohesion)* opposed to the motion is not sufficient to overcome it.

We have seen that ferment or yeast is a body in the state of decomposition, the atoms of which, consequently, are in a state of motion or transposition. Yeast placed in contact with sugar communicates to the elements of that compound the same state, in consequence of which, the constituents of the sugar arrange themselves into new and simpler forms, namely, into alcohol and carbonic acid. In these new compounds the elements are united together by stronger affinities than they were in the sugar, and therefore under the conditions in which they were produced further decomposition is arrested.

We know, also, that the elements of sugar assume totally different arrangements, when the substances which excite their transposition are in a different state of decomposition from the yeast just mentioned. Thus, when sugar is acted on by rennet or putrefying vegetable juices, it is not converted into alcohol and carbonic acid, but into lactic acid, mannite, and gum.

Again, it has been shown..that yeast added to a solution

to vegetable juices which contain gluten as well as sugar, it is reproduced by the decomposition of the former substance.

The yeast with which these liquids are made to ferment, has itself been originally produced from gluten.

The conversion of gluten into yeast in these vegetable juices is dependent on the decomposition (fermentation) of sugar; for, when the sugar has completely disappeared, any gluten which may still remain in the liquid does not suffer change from contact with the newly-deposited yeast, but retains all the characters of gluten.

Yeast is a product of the decomposition of gluten; but it passes into a second stage of decomposition when in contact with water. On account of its being in this state of further change, yeast excites fermentation in a fresh solution of sugar, and if this second saccharine fluid should contain gluten, (should it be *wort*, for example,) yeast is again generated, in consequence of the transposition of the elements of the sugar exciting a similar change in this gluten.

After this explanation, the idea that yeast reproduces itself as seeds reproduce seeds, cannot for a moment be entertained.

From the foregoing facts it follows, that a body in the act of decomposition (it may be named the *exciter*), added to a mixed fluid in which its constituents are contained, can reproduce itself in that fluid, exactly in the same manner as new yeast is produced when yeast is added to liquids containing gluten. This must be more certainly effected when the liquid acted upon contains the body by the metamorphosis of which the *exciter* has been originally formed.

It is also obvious, that if the *exciter* be able to impart

its own state of transformation to one only of the compo-
nent parts of the mixed liquid acted upon, its own repro-
duction may be the consequence of the decomposition of
this one body.

This law may be applied to organic substances forming
part of the animal organism. We know that all the con-
stituents of these substances are formed from the blood,
and that the blood by its nature and constitution is one of
the most complex of all existing matters.

Nature has adapted the blood for the reproduction of
every individual part of the organism ; its principal charac-
ter consists in its component parts being subordinate to
every attraction. These are in a perpetual state of change
or transformation, which is effected in the most various
ways through the influence of the different organs.

The individual organs, such as the stomach, cause all
the organic substances conveyed to them which are
capable of transformation to assume new forms. The
stomach compels the elements of these substances to unite
into a comdound fitted for the formation of the blood.
But the blood possesses no power of causing transforma-
tions ; on the contrary, its principal character consists in
its readily suffering transformations ; and no other matter
can be compared in this respect with it.

Now it is a well-known fact, that when blood, cerebral
substance, gall, pus, and other substances in a state of
putrefaction, are laid upon fresh wounds, vomiting, de-
bility, and at length death, are occasioned. It is also
well known that bodies in anatomical rooms frequently
pass into a state of decomposition which is capable of
imparting itself to the living-body, the smallest cut with
a knife which has been used in their dissection producing
in these cases dangerous consequences.

The poison of bad sausages belongs to this class of noxious substances. Several hundred cases are known in which death has occurred from the use of this kind of food. In Würtemberg especially these cases are very frequent, for there the sausages are prepared from very various materials. Blood, liver, bacon, brains, milk, meal, and bread, are mixed together with salt and spices; the mixture is then put into bladders or intestines, and after being boiled is smoked.

When these sausages are well prepared, they may be preserved for months, and furnish a nourishing savoury food; but when the spices and salt are deficient, and particularly when they are smoked too late or not sufficiently, they undergo a peculiar kind of putrefaction which begins at the centre of the sausage. Without any appreciable escape of gas taking place, they become paler in colour, and more soft and greasy in those parts which have undergone putrefaction, and they are found to contain free lactic acid, or lactate of ammonia; products which are universally formed during the putrefaction of animal and vegetable matters.

The cause of the poisonous nature of these sausages was ascribed at first to hydrocyanic acid, and afterwards to sebacic acid, although neither of these substances had been detected in them. But sebacic acid is no more poisonous than benzoic acid, with which it has so many properties in common; and the symptoms produced are sufficient to show that hydrocyanic acid is not the poison.

The death which is the consequence of poisoning by putrefied sausages succeeds very lingering and remarkable symptoms. There is a gradual wasting of muscular fibre, and of all the constituents of the body similarly

composed ; the patient becomes much emaciated, dries to
a complete mummy, and finally dies. The carcase is stiff
as if frozen, and is not subject to putrefaction. During
the progress of the disease the saliva becomes viscous
and acquires an offensive smell.

Experiments have been made for the purpose of ascer-
taining the presence of some matter in the sausages to
which their poisonous action could be ascribed; but no
such matter has been detected. Boiling water and alcohol
completely destroy the poisonous properties of the sau-
sages, without themselves acquiring similar properties.

Now this is the peculiar character of all substances
which exert an action by virtue of their existing condi-
tion—of those bodies the elements of which are in the
state of decomposition or transposition ; a state which
is destroyed by boiling water and alcohol without the
cause of the influence being imparted to those liquids ;
for a state of action or power cannot be preserved in
a liquid.

Sausages, in the state here described, exercise an
action upon the organism, in consequence of the stomach
and other parts with which they come in contact not
having the power to arrest their decomposition ; and
entering the blood in some way or other, while still pos-
sessing their whole power, they impart their peculiar
action to the constituents of that fluid.

The poisonous properties of decayed sausages are not
destroyed by the stomach as those of the small-pox virus
are. All the substances in the body capable of putrefac-
tion are gradually decomposed during the course of the
disease, and after death nothing remains except fat,
tendons, bones, and a few other substances which are

incapable of putrefying in the conditions afforded by the body.

It is impossible to mistake the *modus operandi* of this poison, for Colin has clearly proved that muscle, urine, cheese, cerebral substance, and other matters, in a state of putrefaction, communicate their own state of decomposition to substances much less prone to change of composition than the blood. When placed in contact with a solution of sugar, they cause its putrefaction, or the transposition of its elements into carbonic acid and alcohol.

When putrefying muscle or pus is placed upon a fresh wound, it occasions disease and death. It is obvious that these substances communicate their own state of putrefaction to the sound blood *from which they were produced,* exactly in the same manner as gluten in a state of decay or putrefaction causes a similar transformation in a solution of sugar.

Poisons of this kind are even generated by the body itself in particular diseases. In small-pox, plague, and syphilis, substances of a peculiar nature are formed from the constituents of the blood. These matters are capable of inducing in the blood of a healthy individual a decomposition similar to that of which they themselves are the subjects; in other words, they produce the same disease. The morbid virus appears to reproduce itself just as seeds appear to reproduce seeds.

The mode of action of a morbid virus exhibits such a strong similarity to the action of yeast upon liquids containing sugar and gluten, that the two processes have been long since compared to one another, although merely for the purpose of illustration   But when the

phenomena attending the action of each respectively are *considered more closely, it will in reality be seen that* their influence depends upon the same cause.

In dry air, and in the absence of moisture, all these poisons remain for a long time unchanged; but when exposed to the air in the moist condition, they lose very rapidly their peculiar properties. In the former case, those conditions are afforded which arrest their decomposition without destroying it; in the latter, all the circumstances necessary for the completion of their decomposition are presented.

The temperature at which water boils, and contact with alcohol, render such poisons inert. Acids, salts of mercury, sulphurous acid, chlorine, iodine, bromine, aromatic substances, volatile oils, and particularly empyreumatic oils, smoke, and a decoction of coffee, completely destroy their contagious properties, in some cases combining with them or otherwise effecting their decomposition. Now all these agents, without exception, retard fermentation, putrefaction, and decay, and when present in sufficient quantity, completely arrest these processes of decomposition.

A peculiar matter to which the poisonous action is due, cannot, we have seen, be extracted from decayed sausages; and it is equally impossible to obtain such a principle from the virus of small-pox or plague, and for this reason, that their peculiar power is due to an active condition recognisable by our senses, only through the phenomena which it produces.

In order to explain the effects of contagious matters, a peculiar principle of life has been ascribed to them—a life similar to that possessed by the germ of a seed, which enables it under favourable conditions to develop and

multiply itself. It would be impossible to find a more correct figurative representation of these phenomena; it is one which is applicable to contagions, as well as to ferment, to animal and vegetable substances in a state of fermentation, putrefaction, or decay, and even to a piece of decaying wood, which by mere contact with fresh wood, causes the latter to undergo gradually the same change and become decayed and mouldered.

If the property possessed by a body of producing such a change in any other substance as causes the reproduction of itself, with all its properties, be regarded as life, then, indeed, all the above phenomena may be ascribed to life. But in that case they must not be considered as the only processes due to vitality, for the above interpretation of the expression embraces the majority of the phenomena which occur in organic chemistry. Life would, according to that view, be admitted to exist in every body in which chemical forces act.

If a body A, for example *oxamide* (a substance scarcely soluble in water, and without the slightest taste), be brought into contact with another compound B, which is to be reproduced; and if this second body be *oxalic acid dissolved* in water; then the following changes are observed to take place:—The oxamide is decomposed by the oxalic acid, provided the conditions necessary for their exercising an action upon one another are present. The elements of water unite with the constituents of oxamide, and *ammonia* is one product formed, and *oxalic acid* the other, both in exactly the proper proportions to combine and form a neutral salt.

Here the contact of oxamide and oxalic acid induces a transformation of the oxamide, which is decomposed into oxalic acid and ammonia. The oxalic acid thus formed,

as well as that originally added, are shared by the am-
monia—or in other words, as much free oxalic acid
exists after the decomposition as before it, and is of
course still possessed of its original power. It matters
not whether the free oxalic acid is that originally added,
or that newly produced ; it is certain that it has been
reproduced in an equal quantity by the decomposition.

If we now add to the same mixture a fresh portion of
oxamide, exactly equal in quantity to that first used, and
treat it in·the same manner, the same decomposition is
repeated; the free oxalic acid enters into combination,
whilst another portion is liberated. In this manner a
very minute quantity of oxalic acid may be made to effect
the decomposition of several hundred pounds of oxamide ;
and one grain of the acid to reproduce itself in unlimited
quantity.

We know that the contact of the virus of small-pox
causes such a change in the blood, as gives rise to the
reproduction of the poison from the constituents of the
fluid. This transformation is not arrested until all the
particles of the blood which are susceptible of the decom-
position have undergone the metamorphosis. We have
just seen that the contact of oxalic acid with oxamide
caused the production of fresh oxalic acid, which in its
turn exercised the same action on a new portion of oxa-
mide. The transformation was only arrested in conse-
quence of the quantity of oxamide present being limited.
In their form both these transformations belong to the
same class. But no one except a person quite unaccus-
tomed to view such changes will ascribe them to a vital
power, although we admit they correspond remarkably to
our common conceptions of life; they are really chemical
processes, dependent upon the common chemical forces.

Our notion of life involves something more than mere reproduction, namely, the idea of an active power exercised *by virtue of a definite form*, and production and generation *in a definite* form. By chemical agency we can produce the constituents of muscular fibre, skin, and hair; but we can form by their means no organised tissue, no organic cell.

The production of organs, the co-operation of a system of organs, and their power not only to produce their component parts from the food presented to them, but to generate *themselves* in their original form and with all their properties, are characters belonging exclusively to organic life, and constitute a form of reproduction independent of chemical powers.

The chemical forces are subject to the invisible cause by which this form is produced. Of the existence of this cause itself we are made aware only by the phenomena which it produces. Its laws must be investigated just as we investigate those of the other powers which effect motion and changes in matter.

The chemical forces are subordinate to this cause of life, just as they are to electricity, heat, mechanical motion, and friction. By the influence of the latter forces, they suffer changes in their direction; an increase or diminution of their intensity, or a complete cessation or reversal of their action.

Such an influence, and no other, is exercised by the vital principle over the chemical forces; but in every case where combination or decomposition takes place, chemical affinity and cohesion are in action.

The vital principle is only known to us through the peculiar form of its instruments; that is, through the organs in which it resides. Hence, whatever kind of

energy a substance may possess, if it is amorphous and
destitute of organs from which the impulse, motion, or
change proceeds, it does not live. Its energy depends in
this case on a chemical action. Light, heat, electricity,
or other influences may increase, diminish, or arrest this
action, but they are not its efficient cause.

In the same way the vital principle governs the che-
mical powers in the living body. All those substances
to which we apply the general name of food, and all the
bodies formed from them in the organism, are chemical
compounds. The vital principle has, therefore, no other
resistance to overcome in order to convert these sub-
stances into component parts of the organism, than the
chemical powers by which their constituents are held
together. If the food possessed life, not merely the
chemical forces, but this vitality, would offer resistance
to the vital force of the organism it nourished.

All substances adapted for assimilation are bodies of a
very complex constitution; their atoms are highly com-
plex, and are held together only by a weak chemical
action. They are formed by the union of two or more
simple compounds; and in proportion as the number of
their atoms augments, their disposition to enter into new
combinations is diminished; that is, they lose the power
of acting chemically upon other bodies.

Their complex nature, however, renders them more
liable to be changed by the agency of external causes,
and thus to suffer decomposition. Any external agency,
in many cases even mechanical friction, is sufficient to
cause a disturbance in the equilibrium of the attraction
of their constituents; they arrange themselves either into
new, more simple, and permanent combinations, or if a

foreign attraction exercise its influence upon it, they arrange themselves in accordance with that attraction.

The special characters of food, that is, of substances fitted for assimilation, are absence of active chemical properties, and the capability of yielding to transformations.

The equilibrium in the chemical attractions of the constituents of the food is disturbed by the vital principle, as we know it may be by many other causes. But the union of its elements, so as to produce new combinations and forms, indicates the presence of a peculiar mode of attraction, and the existence of a power distinct from all other powers of nature, namely, the vital principle.

All bodies of simple composition possess a greater or less disposition to form combinations. Thus, oxalic acid is one of the simplest of the organic acids, while stearic acid is one of the most complex; and the former is the strongest, the latter one of the weakest, in respect to active chemical character. By virtue of this disposition, simple compounds produce changes in every body which offers no resistance to their action; they enter into combination and cause decomposition.

The vital principle opposes to the continual action of the atmosphere moisture and temperature upon the organism; a resistance which is, in a certain degree, invincible. It is by the constant neutralisation and renewal of these external influences that life and motion are maintained.

The greatest wonder in the living organism is the fact that an unfathomable wisdom has made the cause of a continual decomposition or destruction, namely, the sup-

port of the process of respiration, to be the means of renewing the organism and of resisting all the other atmospheric influences, such as those of moisture and changes of temperature.

When a chemical compound of simple constitution is introduced into the stomach or any other part of the organism, it must exercise a chemical action upon all substances with which it comes in contact; for we know the peculiar character of such a body to be an aptitude and power to enter into combinations and effect decompositions.

The chemical action of such a compound is of course opposed by the vital principle. The results produced depend upon the strength of their respective actions: either an equilibrium of both powers is attained, a change being effected without the destruction of the vital principle, in which case *a medicinal effect* is occasioned; or the acting body yields to the superior force of vitality, that is, *it is digested;* or, lastly, the chemical action obtains the ascendancy, *and acts as a poison.*

Every substance may be considered as *nutriment,* which loses its former properties when acted on by the vital principle, and does not exercise a chemical action upon the living organ.

Another class of bodies change the direction, the strength, and intensity of the resisting force (the vital principle), and thus exert a modifying influence upon the functions of its organs. They produce a disturbance in the system, either by their presence or by themselves undergoing a change; these are *medicaments.*

A third class of compounds are called *poisons,* when they possess the property of uniting with organs or with their component parts, and when their power of effecting

this is stronger than the resistance offered by the vital
principle.

The quantity of a substance and its condition must,
obviously, completely change the mode of its chemical
action.

Increase of quantity is known to be equivalent to supe-
rior affinity. Hence a *medicament* administered in exces-
sive quantity may act as a *poison*, and a poison in small
doses as a *medicament*.

Food will act as a poison, that is, it will produce
disease, when it is able to exercise a chemical action by
virtue of its quantity; or, when either its condition or its
presence retards, prevents, or arrests the motion of any
organ.

A compound acts as a poison when all the parts of an
organ with which it is brought into contact enter into
chemical combination with it, while it may operate as a
medicine when it produces only a partial change.

No other component part of the organism can be com-
pared to the blood, in respect of the feeble resistance
which it offers to exterior influences. The blood is not
an organ which is formed, but an organ in the act of for-
mation; indeed, it is the sum of all the organs which are
being formed. The chemical force and the vital principle
hold each other in such perfect equilibrium, that every
disturbance, however trifling, or from whatever cause it
may proceed, effects a change in the blood. This liquid
possesses so little of permanence, that it cannot be removed
from the body without immediately suffering a change,
and cannot come in contact with any organ in the body,
without yielding to its attraction.

The slightest action of a chemical agent upon the blood
exercises an injurious influence; even the momentary

contact with the air in the lungs, although effected through the medium of cells and membranes, alters the colour and other qualities of the blood. Every chemical action propagates itself through the mass of the blood; for example, the active chemical condition of the constituents of a body undergoing decomposition, fermentation, putrefaction, or decay, disturbs the equilibrium between the chemical force and the vital principle in the circulating fluid. Numerous modifications in the composition and condition of the compounds produced from the elements of the blood, result from the conflict of the vital force with the chemical affinity, in their incessant endeavour to overcome one another.

All the characters of the phenomena of contagion tend to disprove the existence of life in contagious matters. They, without doubt, exercise an influence very similar to some processes in the living organism; but the cause of this influence is chemical action, which is capable of being subdued by other chemical actions, by opposed agencies.

Several of the poisons generated in the body by disease lose all their power when introduced into the stomach, but others are not thus destroyed.

It is a fact very decisive of their chemical nature and mode of action, that those poisons which are neutral or alkaline, such as the poisonous matter of the contagious fever in cattle (*typhus contagiosus ruminantium*), or that of the small-pox, lose their whole power of contagion in the stomach; whilst that of sausages, which has an acid reaction, retains all its frightful properties under the same circumstances.

In the former of these cases, the free acid present in the stomach destroys the action of the poison, the chemical properties of which are opposed to it; whilst in the latter

it strengthens, or, at all events, does not offer any impediment to poisonous action.

Microscopical examination has detected peculiar bodies resembling the globules of the blood in malignant putrefying pus, in the matter of vaccine, &c. The presence of these bodies has given weight to the opinion, that contagion proceeds from the development of a diseased organic life; and these formations have been regarded as the living seeds of disease.

This view, which is not adapted to discussion, has led those philosophers who are accustomed to search for explanations of phenomena in forms, to consider the yeast produced by the fermentation of beer as possessed of life. They have imagined it to be composed of animals or plants, which nourish themselves from the sugar in which they are placed, and at the same time yield alcohol and carbonic acid as excrementitious matters*.

It would perhaps appear wonderful, if bodies possessing a crystalline structure and geometrical figure were formed during the processes of fermentation and putrefaction from the organic substances and tissues of organs. We know, on the contrary, that the complete dissolution into organic compounds is preceded by a series of transformations, in which the organic structures gradually resign their forms.

Blood in a state of decomposition may appear to the eye unchanged; and when we recognise the globules of blood in a liquid contagious matter, the utmost that we can thence infer is, that those globules have taken no part in the process of decomposition. All the phosphate of lime may be removed from bones, leaving them trans-

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* Annalen der Pharmacie, Band xxix. S. 93 und 100.

parent and flexible like leather, without the form of the bones being in the smallest degree lost. Again, bones may be burned until they be quite white, and consist merely of a skeleton of phosphate of lime, but they will still possess their original form. In the same way processes of decomposition in the blood may affect individual constituents only of that fluid, which will become destroyed and disappear, whilst its other parts will maintain the original form.

Several kinds of contagion are propagated through the air : so that, according to the view already mentioned, we must ascribe life to a gas, that is, to an aëriform body.

All the supposed proofs of the vitality of contagions are merely ideas and figurative representations, fitted to render the phenomena more easy of apprehension by our senses, without explaining them. These figurative expressions, with which we are so willingly and easily satisfied in all sciences, are the foes of all inquiries into the mysteries of nature; they are like the *fata morgana*, which show us deceitful views of seas, fertile fields, and luscious fruits, but leave us languishing when we have most need of what they promise.

It is certain that the action of contagions is the result of a peculiar influence dependent on chemical forces, and in no way connected with the vital principle. This influence is destroyed by chemical actions, and manifests itself wherever it is not subdued by some antagonist power. Its existence is recognised in a connected series of changes and transformations, in which it causes all substances capable of undergoing similar changes to participate.

An animal substance in the act of decomposition, or a substance generated from the component parts of a living body by disease, communicates its own condition to all

parts of the system capable of entering into the same state, if no cause exist in these parts by which the change is counteracted or destroyed.

Disease is excited by contagion.

The transformations produced by the disease assume a series of forms.

In order to obtain a clear conception of these transformations, we may consider the changes which substances, more simply composed than the living body, suffer from the influence of similar causes. When putrefying blood or yeast in the act of transformation is placed in contact with a solution of sugar, the elements of the latter substance are transposed, so as to form alcohol and carbonic acid.

A piece of the rennet-stomach of a calf in a state of decomposition occasions the elements of sugar to assume a different arrangement. The sugar is converted into lactic acid without the addition or loss of any element. (1 atom of sugar of grapes $C12$ $H12$ $O12$ yields two atoms of lactic acid $= 2$ ($C6$ $H6$ $O6$.)

When the juice of onions or of beet-root is made to ferment at high temperatures, lactic acid, mannite, and gum are formed. Thus, according to the different states of the transposition of the elements of the exciting body, the elements of the sugar arrange themselves in different manners, that is, different products are formed.

The immediate contact of the decomposing substance with the sugar is the cause by which its particles are made to assume new forms and natures. The removal of that substance occasions the cessation of the decomposition of the sugar, so that, should its transformation be completed before the sugar, the latter can suffer no further change.

In none of these processes of decomposition is the exciting body reproduced; for the conditions necessary to its reproduction do not exist in the elements of the sugar.

Just as yeast, putrefying flesh, and the stomach of a calf in a state of decomposition, when introduced into solutions of sugar, effect the transformation of this substance, without being themselves regenerated; in the same manner miasms and certain contagious matters produce diseases in the human organism, by communicating the state of decomposition, of which they themselves are the subject, to certain parts of the organism, without themselves being reproduced in their peculiar form and nature during the progress of the decomposition.

The disease in this case is not *contagious.*

Now, when yeast is introduced into a mixed liquid containing both sugar and gluten, such as wort, the act of decomposition of the sugar effects a change in the form and nature of the gluten, which is, in consequence, also subjected to transformation. As long as some of the fermenting sugar remains, gluten continues to be separated as yeast, and this new matter in its turn excites fermentation in a fresh solution of sugar or wort. If the sugar, however, should be first decomposed, the gluten which remains in solution is not converted into yeast. We see, therefore, that the reproduction of the exciting body here depends—

1. Upon the presence of that substance from which it was originally formed;

2. Upon the presence of a compound which is capable of being decomposed by contact with the exciting body.

If we express in the same terms the reproduction of ·contagious matter in contagious diseases, since it is quite

certain that they must have their origin in the blood, we must admit that the blood of a healthy individual contains substances, by the decomposition of which the exciting body of contagion can be produced.   It must further be admitted, when contagion results, that the blood contains a second constituent capable of being decomposed by the exciting body. It is only in consequence of the conversion of the second constituent, that the original exciting body can be reproduced.

A susceptibility of contagion indicates the presence of a certain quantity of this second body in the blood of a healthy individual.   The susceptibility for the disease and its intensity must augment according to the quantity of that body present in the blood; and in proportion to its diminution or disappearance, the course of the disease will change.

When a quantity, however small, of contagious matter, that is, of the exciting body, is introduced into the blood of a healthy individual, it will be again generated in the blood, just as yeast is reproduced from wort. Its condition of transformation will be communicated to a constituent of the blood; and in consequence of the transformation suffered by this substance, a body identical with or similar to the exciting or contagious matter will be produced from another constituent substance of the blood. The quantity of the exciting body newly produced must constantly augment, if its further transformation or decomposition proceeds more slowly than that of the compound in the blood, the decomposition of which it effects.

If the transformation of the yeast generated in the fermentation of wort proceeded with the same rapidity as that of the particles of the sugar contained in it, both

would simultaneously disappear when the fermentation was completed. But yeast requires a much longer time for decomposition than sugar; so that after the latter has completely disappeared, there remains a much larger quantity of yeast than existed in the fluid at the commencement of the fermentation,—yeast which is still in a state of incessant progressive transformation, and therefore possessed of its peculiar property.

The state of change or decomposition which affects one particle of blood is imparted to a second, a third, and at last to all the particles of blood in the whole body. It is communicated in like manner to the blood of another individual, to that of a third person, and so on—or in other words, the disease is excited in them also.

It is quite certain that a number of peculiar substances exist in the blood of some men and animals, which are absent from the blood of others.

The blood of the same individual contains, in childhood and youth, variable quantities of substances, which are absent from it in other stages of growth. The susceptibility of contagion by peculiar exciting bodies in childhood, indicates a propagation and regeneration of the exciting bodies, in consequence of the transformation of certain substances which are present in the blood, and in the absence of which no contagion could ensue. The form of a disease is termed *benignant*, when the transformations are perfected on constituents of the body which are not essential to life, without the other parts taking a share in the decomposition; it is termed *malignant* when they affect essential organs.

It cannot be supposed that the different changes in the blood, by which its constituents are converted into fat, muscular fibre, substances of the brain and nerves, bones,

hair, &c., and the transformation of food into blood, can
take place without the simultaneous formation of new
compounds which require to be removed from the body
by the organs of excretion.

In an adult these excretions do not vary much either in
their nature or quantity. The food taken is not employed
in increasing the size of the body, but merely for the
purpose of replacing any substances which may be con-
sumed by the various actions in the organism; every
motion, every manifestation of organic properties, and
every organic action being attended by a change in the
material of the body, and by the assumption of a new
form by its constituents*.

But in a child this normal condition of sustenance is
accompanied by an abnormal condition of growth and
increase in the size of the body, and of each individual
part of it. Hence there must be a much larger quantity
of foreign substances, not belonging to the organism,
diffused through every part of the blood in the body of a
young individual.

When the organs of secretion are in proper action,
these substances will be removed from the system; but
when the functions of those organs are impeded, they will
remain in the blood or become accumulated in particular
parts of the body. The skin, lungs, and other organs,
assume the functions of the diseased secreting organs, and
the accumulated substances are eliminated by them. If,

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* The experiments of Barruel upon the different odours emitted from
blood on the addition of sulphuric acid, prove that peculiar substances are
contained in the blood of different individuals; the blood of a man of a
fair complexion and that of a man of dark complexion were found to yield
different odours; the blood of animals also differed in this respect very
perceptibly from that of man.

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when thus exhaled, these substances happen to be in the
state of progressive transformation, they are contagious ;
that is, they are able to produce the same state of disease
in another healthy organism, provided the latter organism
is susceptible of their action—or in other words, contains
a matter capable of suffering the same process of decom-
position.

The production of matters of this kind, which render
the body susceptible of contagion, may be occasioned by
the manner of living, or by the nutriment taken by an
individual. A superabundance of strong and otherwise
wholesome food may produce them, as well as a deficiency
of nutriment, uncleanliness, or even the use of decayed
substances as food.

All these conditions for contagion must be considered
as accidental. Their formation and accumulation in the
body may be prevented, and they may even be removed
from it without disturbing its most important functions or
health. Their presence is not necessary to life.

The action, as well as the generation of the matter of
contagion, is, according to this view, a chemical process
participated in by all substances in the living body, and
by all the constituents of those organs in which the vital
principle does not overcome the chemical action. The
contagion, accordingly, either spreads itself over every
part of the body, or is confined particularly to certain
organs, that is, the disease attacks all the organs or only
a few of them, according to the feebleness or intensity of
their resistance.

In the abstract chemical sense, reproduction of a con-
tagion depends upon the presence of two substances, one
of which becomes completely decomposed, but commu-
nicates its own state of transformation to the second.

The second substance thus thrown into a state of decom-
position is the newly-formed contagion.

The second substance must have been originally a con-
stituent of the blood: the first may be a body acciden-
tally present; but it may also be a matter necessary to
life. If both be constituents indispensable for the sup-
port of the vital functions of certain principal organs,
death is the consequence of their transformation. But if
the absence of the one substance which was a constituent
of the blood do not cause an immediate cessation of the
functions of the most important organs, if they continue
in their action, although in an abnormal condition, con-
valescence ensues. In this case the products of the
transformations still existing in the blood are used for
assimilation, and at this period secretions of a peculiar
nature are produced.

When the constituent removed from the blood is a
product of an unnatural manner of living, or when its
formation takes place only at a certain age, the suscepti-
bility of contagion ceases upon its disappearance.

The effects of vaccine matter indicate that an accidental
constituent of the blood is destroyed by a peculiar pro-
cess of decomposition, which does not affect the other
constituents of the circulating fluid.

If the manner in which the precipitated *yeast* of Bava-
rian beer acts (page 324) be called to mind, the *modus
operandi* of vaccine lymph can scarcely be matter of
doubt.

Both the kind of yeast here referred to and the ordi-
nary ferment are formed from gluten, just as the vaccine
virus and the matter of small-pox are produced from the
blood. Ordinary yeast and the virus of human small

the former in vegetable juices, the latter in blood, in both
of which fluids respectively their constituents are con-
tained, and they are reproduced from these fluids with all
their characteristic properties.   The precipitated yeast
of Bavarian beer, on the other hand, acts entirely upon
the sugar of the fermenting liquid, and occasions a very
protracted decomposition of it, in which the gluten which
is also present takes no part.   But the air exercises an
influence upon the latter substance, and causes it to
assume a new form and nature, in consequence of which
this kind of yeast also is reproduced.

The action of the virus of cow-pox is analogous to that
of the low yeast; it communicates its own state of decom-
position to a matter in the blood, and from a second
matter is itself regenerated, but by a totally different
mode of decomposition; the product possesses the mild
form, and all the properties of the lymph of cow-pox.

The susceptibility of infection by the virus of human
small-pox must cease after vaccination, for the substance
to the presence of which this susceptibility is owing has
been removed from the body by a peculiar process of de-
composition artificially excited.   But this substance may
be again generated in the same individual so that he may
again become liable to contagion, and a second or a third
vaccination will again remove the peculiar substance from
the system.

Chemical actions are propagated in no organs so easily
as in the lungs, and it is well known that diseases of the
lungs are above all others frequent and dangerous.

If it is assumed that chemical action and the vital prin-
ciple mutually balance each other in the blood, it must
farther be supposed that the chemical powers will have a
certain degree of preponderance in the lungs, where the

air and blood are in immediate contact; for these organs are fitted by nature to favour chemical action; they offer no resistance to the changes experienced by the venous blood.

The contact of air with venous blood is limited to a very short period of time by the motion of the heart, and any change beyond a determinate point is, in a certain degree, prevented by the rapid removal of the blood which has become arterialised. Any disturbance in the functions of the heart, and any chemical action from without, even though weak, occasions a change in the process of respiration. Solid substances also, such as dust from vegetable, animal, or inorganic bodies, act in the same way as they do in a saturated solution of a salt in the act of crystallisation, that is, they occasion a deposition of solid matters from the blood, by which the action of the air upon the latter is altered or prevented.

When gaseous and decomposing substances, or those which exercise a chemical action, such as sulphuretted hydrogen and carbonic acid, obtain access to the lungs, they meet with less resistance in this organ than in any other. The chemical process of slow combustion in the lungs is accelerated by all substances in a state of decay or putrefaction, by ammonia and alkalies; but it is retarded by empyreumatic substances, volatile oils, and acids. Sulphuretted hydrogen produces immediate decomposition of the blood, and sulphurous acid combines with the substance of the tissues, the cells, and membranes.

When the process of respiration is modified by contact with a matter in the progress of decay, when this matter communicates the state of decomposition, of which it is the subject, to the blood, disease is produced.

If the matter undergoing decomposition is the product of a disease, it is called contagion; but if it is a product of the decay or putrefaction of animal and vegetable substances, or if it acts by its chemical properties, (not by the state in which it is,) and therefore enters into combination with parts of the body, or causes their decomposition, it is termed *miasm*.

Gaseous contagious matter is a miasm emitted from blood, and capable of generating itself again in blood.

But miasm, properly so called, causes disease without being itself reproduced.

All the observations hitherto made upon gaseous contagious matters prove, that they also are substances in a state of decomposition. When vessels filled with ice are placed in air impregnated with gaseous contagious matter, their outer surfaces become covered with water containing a certain quantity of this matter in solution. This water soon becomes turbid, and in common language putrefies, or, to describe the change more correctly, the state of decomposition of the dissolved contagious matter is completed in the water.

All gases emitted from putrefying animal and vegetable substances in processes of disease, generally possess a peculiar nauseous offensive smell, a circumstance which, in most cases, proves the presence of a body in a state of decomposition. Smell itself may in many cases be considered as a reaction of the nerves of smell, or as a resistance offered by the vital powers to chemical action.

Many metals emit a peculiar odour when rubbed, but this is the case with none of the precious metals,—those which suffer no change when exposed to air and moisture. Arsenic, phosphorus, musk, the oils of linseed, lemons, turpentine, rue, and peppermint, possess an odour

only when they are in the act of eremacausis (oxidation
at common temperatures).

The odour of gaseous contagious matters is owing to
the same cause; but it is also generally accompanied by
ammonia, which may be considered in many cases as the
means through which the contagious matter receives a
gaseous form, just as it is the means of causing the smell
of innumerable substances of little volatility, and of many
which have no odour. (Robiquet.)*

Ammonia is very generally produced in cases of disease;
it is always emitted in those in which contagion is gene-
rated, and is an invariable product of the decomposition
of animal matter. The presence of ammonia in the air
of chambers in which diseased patients lie, particularly of
those afflicted with a contagious disease, may be readily
detected ; for the moisture condensed by ice in the man-
ner just described, produces a white precipitate in a solu-
tion of corrosive sublimate, just as a solution of ammonia
does. The ammoniacal salts also, which are obtained
by the evaporation of rain-water after an acid has been
added, when treated with lime so as to set free their am-
monia, emit an odour most closely resembling that of
corpses, or the peculiar smell of dunghills.

By evaporating acids in air containing gaseous con-
tagions, the ammonia is neutralised, and we thus prevent
further decomposition, and destroy the power of the
contagion, that is, its state of chemical change. Muriatic
and acetic acids, and in several cases nitric acid, are to be
preferred for this purpose before all others. Chlorine
also is a substance which destroys ammonia and organic
bodies with much facility; but it exerts such an injurious
and prejudicial influence upon the lungs, that it may

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* Ann. de Chim. et de Phys. xv. 27.

be classed amongst the moist poisonous bodies known, and should never be employed in places in which men breathe.

Carbonic acid and sulphuretted hydrogen, which are frequently evolved from the earth in cellars, mines, wells, sewers, and other places, are amongst the most pernicious miasms. The former may be removed from the air by alkalies; the latter, by burning sulphur (sulphurous acid), or by the evaporation of nitric acid.

The characters of many organic compounds are well worthy of the attention and study both of physiologists and pathologists, more especially in relation to the mode of action of medicines and poisons.

Several of such compounds are known, which to all appearance are quite indifferent substances, and yet cannot be brought into contact with one another in water without suffering a complete transformation. All substances which thus suffer a mutual decomposition, possess complex atoms; they belong to the highest order of chemical compounds. For example, amygdalin, a constituent of bitter almonds, is a perfectly neutral body, of a slightly bitter taste, and very easily soluble in water. But when it is introduced into a watery solution of synaptas, (a constituent of sweet almonds,) it disappears completely without the disengagement of any gas, and the water is found to contain free hydrocyanic acid, hydruret of benzule (oil of bitter almonds), a peculiar acid and sugar, all substances of which merely the elements existed in the amygdalin. The same decomposition is effected when bitter almonds, which contain the same white matter as the sweet, are rubbed into a powder and moistened with water. Hence it happens that bitter almonds pounded and digested in alcohol, yield no oil of bitter almonds containing hydro-

cyanic acid, by distillation with water; for the substance which occasions the formation of those volatile substances, is dissolved by alcohol without change, and is therefore extracted from the pounded almonds. Pounded bitter almonds contain no amygdalin, also, after having been moistened with water, for that substance is completely decomposed when they are thus treated.

No volatile compounds can be detected by their smell in the seeds of the *Sinapis alba* and *S. nigra.* A fixed oil of a mild taste is obtained from them by pressure, but no trace of a volatile substance. If, however, the seeds are rubbed to a fine powder, and subjected to distillation with water, a volatile oil of a very pungent taste and smell passes over along with the steam. But if, on the contrary, the seeds are treated with alcohol previously to their distillation with water, the residue does not yield a volatile oil. The alcohol contains a crystalline body called sinapin, and several other bodies. These do not possess the characteristic pungency of the oil, but it is by the contact of them with water, and with the albuminous constituents of the seeds, that the volatile oil is formed.

Thus bodies regarded as absolutely indifferent in inorganic chemistry, on account of their possessing no prominent chemical characters, when placed in contact with one another, mutually decompose each other. Their constituents arrange themselves in a peculiar manner, so as to form new combinations; a complex atom dividing into two or more atoms of less complex constitution, in consequence of a mere disturbance in the attraction of their elements.

The white constituents of the almonds and mustard which resemble coagulated albumen, must be in a peculiar

state in order to exert their action upon amygdalin, and upon those constituents of mustard from which the volatile pungent oil is produced. If almonds, after being blanched and pounded, are thrown into boiling water, or treated with hot alcohol, with mineral acids, or with salts of mercury, their power to effect a decomposition in amygdalin is completely destroyed. Synaptas is an azotised body which cannot be preserved when dissolved in water. Its solution becomes rapidly turbid, deposits a white precipitate, and acquires the offensive smell of putrefying bodies.

It is exceedingly probable that the peculiar state of transposition into which the elements of synaptas are thrown when dissolved in water, may be the cause of the decomposition of amygdalin, and formation of the new products arising from it. The action of synaptas in this respect is very similar to that of rennet upon sugar.

Malt, and the germinating seeds of corn in general, contain a substance called *diastase*, which is formed from the gluten contained in them, and cannot be brought in contact with starch and water, without effecting a change in the starch.

When bruised malt is strewed upon warm starch made into a paste with water, the paste after a few minutes becomes quite liquid, and the water is found to contain, in place of starch, a substance in many respects similar to gum. But when more malt is added and the heat longer continued, the liquid acquires a sweet taste, and all the starch is found to be converted into sugar of grapes.

The elements of diastase have at the same time arranged themselves into new combinations.

The conversion of the starch contained in food into sugar of grapes in diabetes, indicates that amongst the

constituents of some one organ of the body a substance
or substances exist in a state of chemical action, to which
the vital principle of the diseased organ opposes no
resistance.   The component parts of the organ must
suffer changes simultaneously with the starch, so that the
more starch is furnished to it, the more energetic and
intense the disease must become ; while if only food
which is incapable of suffering such transformations from
the same cause is supplied, and the vital energy is
strengthened by stimulant remedies and strong nourish-
ment, the chemical action may finally be subdued, or in
other words, the disease cured.

The conversion of starch into sugar may also be effected
by pure gluten, and by dilute mineral acids.

From all the preceding facts, we see that very various
transpositions, and changes of composition and proper-
ties, may be produced in complex organic molecules, by
every cause which occasions a disturbance in the attrac-
tion of their elements.

When moist copper is exposed to air containing car-
bonic acid, the contact of this acid increases the affinity of
the metal for the oxygen of the air in so great a degree
that they combine, and the surface of the copper becomes
covered with green carbonate of copper.   Two bodies,
which possess the power of combining together, assume,
however, opposite electric conditions at the moment at
which they come in contact.

When copper is placed in contact with iron, a peculiar
electric condition is excited, in consequence of which the
property of the copper to unite with oxygen is destroyed,
and the metal remains quite bright.

When formate of ammonia is exposed to a temperature
of 388° F. (180° C.) the intensity and direction of the

chemical force undergo a change, and the conditions under which the elements of this compound are enabled to remain in the same form cease to be present. The elements, therefore, arrange themselves in a new form; hydrocyanic acid and water being the results of the change.

Mechanical motion, friction, or agitation, is sufficient to cause a new disposition of the constituents of fulminating silver and mercury, that is, to effect another arrangement of their elements, in consequence of which new compounds are formed.

We know that electricity and heat possess a decided influence upon the exercise of chemical affinity; and that the attractions of substances for one another are subordinate to numerous causes which change the condition of these substances, by altering the direction of their attractions. In the same manner, therefore, the exercise of chemical powers in the living organism is dependent upon the vital principle.

The power of elements to unite together, and to form peculiar compounds, which are generated in animals and vegetables, is chemical affinity; but the cause by which they are prevented from arranging themselves according to the degrees of their natural attractions—the cause, therefore, by which they are made to assume their peculiar order and form in the body—is the vital principle.

After the removal of the cause which forced their union —that is, after the extinction of life—most organic atoms retain their condition, form, and nature, only by a *vis inertiæ;* for a great law of nature proves that matter does not possess the power of spontaneous action. A body in motion loses its motion only when a resistance is opposed to it; and a body at rest cannot be put in motion, or into

any action whatever, without the operation of some exterior cause.

The same numerous causes which are opposed to the formation of complex organic molecules, under ordinary circumstances, occasion their decomposition and transfor- mations when the only antagonist power, the vital prin- ciple, no longer counteracts the influence of those causes. Contact with air and the most feeble chemical action now effect changes in the complex molecules ; even the pre- sence of any body the particles of which are undergoing motion or transposition, is often sufficient to destroy their state of rest, and to disturb the statical equilibrium in the attractions of their constituent elements. An immediate consequence of this is that they arrange themselves accord- ing to the different degrees of their mutual attractions, and that new compounds are formed in which chemical affinity has the ascendancy, and opposes any further change, while the conditions under which these com- pounds were formed remain unaltered.

TABLES:

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In general all the weights and measures employed in this
edition are those of the English standard. In a few cases
only, the Hessian weights and measures have been retained.
In these the numbers do not represent absolute quantities,
but are merely intended to denote a proportion to other
numbers. This has been done to avoid any unnecessary
intricacy in the calculations, and to present whole numbers
to the reader, without distracting his attention by decimal
parts. For those, however, who wish to be acquainted with
the exact English quantities, a Table is given below.

1 lb. English is equal to 0·90719 lbs. Hessian ; hence, about
one-tenth less than the latter.

1 lb. Hessian is equal to	1·102 lbs.	English.
2 lbs. Hessian are equal to	2·204	,,
3	3·306	,,
4	4·409	,,
5	5·511	,,
6	6·612	,,
7	7·716	,,
8	8·818	,,
9	9·92	,,
10	11·02	,,
20	22·04	,,
30	33·06	,,
40	44·09	,,
50	55·11	,,
60	66·12	,,
70	77·16	,,
80	88·18	,,
90	99·29	,,
100	110·2	,,
200	220·4	,,
300	330·6	,,
400	440·9	,,
500	551·1	,,
·600	661·2	,,
700	771·6	,,
800 . . . . . ·'.	881·8	,,
900	992·0	,,
1000	1102·0	,,

SQUARE FEET.

The Hessian acre is equal to 40,000 Hessian square feet, or 26,911 English square feet; 1 English square foot being equal to 1·4864 Hessian. The following is a Table to save the trouble of calculation. The Table is only stated to the figure 10, but by removing the decimal point one or two figures, the whole series given in the case of the pounds will also be obtained.

1 Square Foot Hessian is equal to 0·612 Square Foot English.

2 feet	.	.	.	.	.	.	1·345	,,	
3	.	.	.	.	.	. .	2·018	feet	
4	.	.	.	.	.	. .	2·691	,,	
5	.	.	.	.	.	. .	3·363	,,	
6	.	.	.	.	.	.	4·036	,,	
7 .	.	.	.	.	.	. .	4·709	,,	
8	.	.	.	.	.	.	5·382	,,	
9	.	.	.	.	.	. .	6·054	,,	
10	.	.	.	.	.	.	6·727	,,	

CUBIC FEET.

One English cubic foot contains 1·81218 of a Hessian cubic foot; the Hessian and English cubic inch may be considered as equal, one English cubic inch containing 1·048715 Hessian cubic inch.

1 cubic foot Hessian is equal to 0·551 cubic foot English.

2 feet	.	.	.	.	.	.	1·103	,,
3	.	.	.	.	.	. .	1·655	,,
4	.	.	.	.	.	.	2·207	feet
5	.	.	.	.	.	.	2·759	,,
6	.	.	.	.	.	.	3·311	,,
7	.	.	.	.	.	. .	3·863	,,
8	.	.	.	.	.	.	4·415	,,
9	.	.	.	.	.	.	4·966	,,
10	.	.	.	.	.	.	5·518	,,

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