Vaughan (D)

A NEW SYSTEM

OF

VEGETABLE PHYSIOLOGY,

DESIGNED TO ACCOUNT SATISFACTORILY FOR THE PHENOMENA WHICH TAKE PLACE IN THE VEGETABLE KINGDOM; AND TO SHOW THE INFLUENCE OF LIGHT, HEAT, AND ELECTRICITY

ON VEGETATION.

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BY DANIEL VAUGHAN.

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TO THE PUBLIC.

For some time my attention has been directed to the study of Organic Chemistry. My first object was to try how far this science might be available to remove the distress which the potatoe disease produced in many parts of Europe; but the total failure of Chemists to remedy the evil, or even to discover the cause of it, led me to doubt some fundamental theories in Agricultural Chemistry, and Vegetable Physiology. The result of a diligent examination of these sciences, was a discovery of many errors and inconsistencies in them. A new theory which, I hope, will be found free from these objections, is offered to the consideration of the public. A few more short essays will be required for a full explanation of it. I intend, after a short time, to exhibit an apparatus for making some experiments alluded to in the course of this work, and also a contrivance which, I confidently hope, will be successful in preventing the Potatoe-Rot, and several other diseases of vegetables.

DANIEL VAUGHAN.

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A NEW SYSTEM OF

VEGETABLE PHYSIOLOGY.

1. To acquire a knowledge of the nature of vegetation, and to understand the various circumstances on which it depends, it is necessary to examine several facts, which science or practical observation has made known respecting vegetables. Chemistry, in its present improved state, has enabled us to discover their compostion, their structure, and the many changes to which they are subject; while equally important discoveries, with regard to their growth, have resulted from continual experience in the art of culture. Of the information collected from these sources I have freely availed myself, in the formation of theory contained in the following pages. The principles on which it is founded I shall endeavor to explain in a very concise manner, as I intend to treat more fully on the subject on some future occasion. The necessity of a well established theory on vegetation, is manifest to all conversant with the contradictory opinions, which have been advanced on the subject by writers on Vegetable Physiology.

2. Every inquisitive observer of nature, on taking a survey of the vegetable kingdom, must be led to inquire: From what source do plants derive their food? In what manner is this food conveyed to them? What renews the supply and prevents it from being exhausted? I shall proceed to examine and to answer these important questions which have, for a considerable time, occasioned so much controversy between chemists and vegetable physiologists. Indeed, most of the vague and erroneous opinions on this subject, may be traced to the loose method of reasoning adopted by many theoretical writers, whose systems are based upon a supposed analogy between all the operations of nature. By them, the flow of the sap in trees, is compared to the circulation of the blood in animals; the decomposition of carbonic acid, by the leaves of plants, is ascribed to the same principle which causes its formation in our lungs, during respiration: vegetables are supposed to possess juices and organs corresponding to those of animals, and performing similar functions; while all the circumstances attending their growth, are imagined to be sufficiently explained when compared to some operation of animated nature. There is, indeed, no proof that such analogies should necessarily exist; and, even if there were, comparisons of this kind would throw little light on vegetation, as the animal functions are, perhaps, more difficult to be

accounted for than those of vegetables, and farther removed from the control of experimental inquiry. In the present essay, I shall adopt a more rigorous mode of investigation, and my proofs and illustrations shall be drawn from well established facts, and satisfactory experiments.

3. It has been ascertained by chemists, that vegetables are composed principally of carbon, oxygen, and hydrogen. The two last substances are the elements of which water is composed; and oxygen forms a large portion of the atmospheric air. Carbon is found pure only in the diamond, but is the principal ingredient of charcoal, pit-coal, bitumen, and several other productions of nature. During combustion, the carbon of these substances unites with the oxygen of the air, and forms carbonic acid—a gas extremely injurious, and often fatal to animal life. This gas exists in large quantities in limestone, chalk, and several other minerals, and is even combined with the air we breathe. It is also ejected from volcanoes, and from some subterranean caverns; it is produced by the decay of plants, and by the respiration of men and animals; a fact which accounts for the injurious effects produced on the human system, when we remain for a considerable time in a confined portion of air, or in an apartment badly ventillated. To reflect on the incessant supply of carbonic acid, from these and other sources, would, at first sight, make us apprehend that the accumulation of this noxions gas in our atmosphere, should, at some future time, cause the extinction of the human race. The immense extent of the atmosphere, is a sufficient security against the immediate occurrence of such a calamity; but the result of the chemical analysis of the air, at different times, must dispel all such alarms for the safety of mankind, even at the most distant period. Notwithstanding some small variations, at different seasons of the year, the mean quantity of carbonic acid in our atmosphere is always found to be the same; and this does not amount to what might be produced in a single century by the agents concerned in its production, though they have been in operation since the creation of the world.

4. Since it is evident, from these facts, that carbonic acid is removed from the air, we must next inquire, what are the means employed by nature for its removal. According to the theory of Priestly, the leaves and green parts of plants possess the power of decomposing carbonic acid, and retain the carbon, while they emit the oxygen. In this manner the air, which has been poisoned by animals, is purified by vegetables, and supplies them with carbon; their other ingredients being derived from the soil on which they grow, or from the water which they receive from various sources. It appears, indeed, from several experiments, that carbonic acid, when applied to plants in a small quantity, is decomposed during the day, and oxygen is liberated. During the night, however, oxygen is absorbed, the formation of carbonic acid takes place, and this is attended with a loss of part of the carbon acquired during the day.

5. Many facts appear favorable to the opinion, that plants obtain a great portion of nourishment from the atmosphere. A quantity of carbon is taken away every year, from a forest or meadow, in the form of

wood or hay, and this removal is attended with little, or perhaps, no diminution of the vegetable mould of the soil. From this it has been inferred, that vegetable mould is not the source of carbon in plants.— We are told that Van Halmont planted a willow in a certain portion of vegetable earth, and having applied no nourishment for five years, but distilled water, he found, at the expiration of that time, that his tree had increased several pounds in weight, while the earth in which it grew lost but a few ounces. Du Hamel was equally successful in raising an oak, for eight years, in the same manner; but, though he informs us that his tree died from a neglect of watering, it appears doubtful whether it could be made to survive much longer; for he admits that it grew less every succeeding year, that the roots were in an unsound state, and that the whole exhibited symptoms of decay. It must be observed, that the presence of vegetable mould, or some organic matter of the same nature, is indispensably neccessary to the growth of all plants, except two, from the tropical climates, which, it is said, can be made to vegetate in water alone. Seeds, when sown in several inorganic substances, were, indeed, found to germinate; but the plants they produced died before the development of the third leaf. Even carbonic acid, which was supposed to be the food of plants, was found to cause their speedy decay, when applied in any considerable quantity; and, in the diffused light of the sun, any addition to the amount already in the air, seems to be as injurious to vegetable as it is to animal life.

6. These facts, and others of the same nature, have given rise to various conflicting opinions among theorists, in relation to the source from which plants derive their carbon, and the form in which it enters into their composition. Some vegetable Physiologists maintain that the entire supply is obtained exclusively from *humus*, or vegetable mould, which is dissolved by the water in the soil, absorbed by the roots, and transformed into the different products of vegetation. According to others, plants are supported by humus and carbonic acid, conjointly; the former being taken up in their roots; the latter being absorbed and decomposed by their leaves. Liebig, Lindley, Daubeny, and other modern writers, contend that the supply of carbon is derived entirely from carbonic acid; and that humus sustains vegetation by emitting this gas, when it is required for the development of the leaves, and other organs of plants.

7. Without discussing the comparative merits of these theories, or the objections which may be readily urged against them, I shall dwell on an erroneous idea, commonly entertained, in regard to the formation of humus; as it may be considered the source of all vague and contradictory opinions on Vegetable Physiology. Humus is a dark friable substance, composed of carbon, oxygen, hydrogen, and, perhaps, a small portion of nitrogen. As chemists have hitherto failed to form it by the direct union of its elements, they ascribe its formation to the decay or putrifaction of vegetable matter. The decay, they suppose, not only adequate to maintain the existing quantity of humus in the soil, but even to cause the first formation, where none previously existed. To shew the absurdity of this opinion, it may be necessary to refer to

the experiments of Saussure and Boussingault, the only experiments which seem to countenance such a supposition. Though plants, when made to vegetate without mould, died in a very short time, these philosophers found that many seeds, in such circumstances, produced plants of double their own weight, and they concluded that this imperfect vegetation would contribute to augment the carbon of the soil. This fact has been supposed to sustain the opinion that the seeds, which are imagined to be continually floating in the atmosphere, fall to the ground and produce plants, which, by their decay, increase the vegetable mould in the soil. In this manner, seeds and plants are supposed to have caused the formation of vegetable mould on barren rocks—on islands recovered from the sea—over the lava which had been ejected from volcanoes—and on the surface of the earth soon after the creation of the world.

8. Had these experiments been properly conducted, it would be found that vegetation is always attended with a diminution, instead of an increase of the carbon of the soil; and that vegetable mould could not be formed by decay alone. The diminutive plants alluded to, should be permitted to decay; and then it should be ascertained how the mould, which remained, compared in weight with the seeds from which they grew. If it weighed less than the seeds—(as may be confidently predicted)—it would indicate a loss of carbon by vegetation; if it weighed more, we could not be assured of a permanent increase of carbon in the soil, until it should be proved that none were afterwards wasted, unless what was wholly appropriated in the formation of other vegetables.

9. Without having recourse to conjecture, the most decisive evidence in regard to this theory, may be deduced from certain facts respecting the action of humus on vegetation. "Part of its carbon" says a modern writer, "unites with the oxygen of the air, and forms carbonic acid, which the green parts of the plants readily absorb; while its hydrogen, uniting with oxygen, forms water, which serves to nourish the roots." Whatever difference of opinion may exist about the nutritive qualities of carbonic acid to vegetables, it is agreed, by all writers, and cannot be questioned, that the formation of water takes place at the expense of the humus; and that the water exhaled from the land, during summer, is produced in this manner. During this kind of respiration, which must not be confounded with evaporation, an astonishing quantity of water is given out from the soil. According to some experiments, it amounted in one day, to about 16000 pounds from an acre of land, when no rain had fallen for several weeks before.

Now, since it has been proved, by chemical analysis, that one pound of water contains more hydrogen than double the quantity of humus; to form these 16000 pounds of water, there must be expended more than 30,000 pounds of humus—a quantity of organic matter greater than could be yielded by the most luxuriant crop, and, consequently, far greater than what would remain, were the crop allowed to suffer decay or putrifaction.

10. Thus, it appears that more humus is expended in a single day,

than could be produced, on an average, during a whole year, by the putrifaction. Experimenters may, perhaps, have exaggerated the amount of water exhaled from the land; but, we may rest assured, that not one per cent. of the humus of the soil is produced by the decay of vegetable matter. We must not forget, also, that a large quantity of humus is carried away to the ocean, by the waters which run from the land, since it is liable to be dissolved by them, as mell as by the water absorbed by vegetables. But it may even be questioned whether the small portion of humus left after vegetable decay, has any nutritive qualities. Liebig has shown that it cannot afford any nutriment to vegetables, by dissolving in the water which their roots absorb; while other physiologists are equally successful in proving that it cannot, by emitting carbonic acid, impart any nourishment to the leaues or to the roots of plants.

11. Since the decay of vegetable matter is inadequate to produce the necessary quantity of humus, or to supply the waste to which it is subject, I shall now consider how this substance is formed. I design to prove that the decomposition of carbonic acid, and the formation of humus, are accomplished by one operation. The decomposition of carbonic acid, on a large scale, appears so difficult that it is ascribed by chemists to the vital principle of plants. I intend to shew that it can be effected by the evaporation of water at low temperature—a process generally taking place during the day. I have ascertained by experiments, during the last year, that such is the effect of the evaporation of water; and a number of facts prove satisfactorily, that this, and the action of light, are the means employed by nature for decomposing carbonic acid, and forming the greater part of humus, and its various modifications.

The principle through which evaporation promotes this decomposition, seems to be intimately connected, if not identical, with negative electricity. It is, indeed, maintained by most philosophers, that negative electricity attends the formation of vapor, which they suppose to have an increased capacity for electricity, as well as for heat. It may, however, be more reasonable to suppose, that the attrition of the evaporating particles of water against the air, would give rise to such electrical excitement. This opinion is strengthened by the fact that the effect is not produced, in any great degree, when vapor is formed at a very high temperature, or in an exhausted receiver. Without entering into a discussion on the nature of the imponderable elements, I shall observe, that heat exercises an influence diametrically opposite to that of light, in these changes; the first promoting the formation of carbonic acid, and the latter tending to effect its decomposition.

13. Besides causing the fixation of carbon from the atmosphere, and acting as an deoxidating agent in other instances, evaporation tends to impart solidity and insolubility to several substances, without sensibly altering their composition. Humus is rendered insoluble when moistened and dried in the open air. The extractive matter of vegetables loses its solubility under the same circumstances. A concentrated solution of sulphate of soda, will not crystallize in a flask which is

tightly corked; but the crystallization will commence if the cork be removed, and its contents briskly shaken. This phenomenon has not been satisfactorily accounted for by chemists, and Guy Lussac has shown that it does not depend on the pressure of the atmosphere. It is no doubt due to the evaporation of the water on the admission of the air, and the agitation of the solution which takes place. The same effect is perceptible in churning cream or milk, when evaporation of the same nature causes the insolubility of the butter, and separates it from the milk, in which it was previously dissolved. Perhaps it may not be absurd to ascribe to the same cause the hardening of mortar, which recent experiments prove, is not owing to the affinity of the lime for sand, nor to its combination with the carbonic acid of the air.—(Mahan.)

14. The condensation of vapor, as might be expected, tends to produce the very opposite effect—owing to the influence of positive electricity. It promotes the formation of carbonic acid, and imparts to several substances, especially to vegetable compounds, solubility and a tendency to undergo decomposition. These effects are favored by the presence of heat, but are counteracted, in some degree, by the influence of light. We may also suppose, that the expansion and condensation of bodies in general, and many other operations of nature, which produce negative or positive electricity, should be attended with the same effects as the formation and condensation of vapor. But the consideration of those agents I shall defer, as they are less concerned in vegetation on land, though they act an important part in the growth of marine plants, beneath the surface of the ocean.

15. The leaves of plants, on account of their peculiar form, are very proper receptacles for the moisture supplied by the dew, by the rain, and by the soil. The evaporation of this from their surfaces, during the day, with the co-operation of the solar light, gives rise to the decomposition of carbonic acid, and the fixation of carbon. At night, in consequence of the condensation of the watery vapor into dews, carbonic acid is formed at the expense of part of the carbon acquired during the day. These views are confirmed by the experiments to which I have alluded in No. 4. The reason why experimenters have been so unsuccessful in their attempts to make plants grow in a confined atmosphere, though sufficiently impregnated with carbonic acid, was evidently because evaporation was suspended, when the confined air became saturated with moisture.

16. It is not, however, to be imagined that this decomposing property is confined exclusively to the leaves, and green parts of plants; but it is also visible in several operations of nature. Having placed a sprig of mint in water impregnated with carbonic acid, and exposed to the rays of the sun, Prestly found that, after some time, the carbonic acid was no longer present in the water. But this decomposition of the acid, which he attributed to the mint, was evidently due to evaporation and the solar rays. The water of spring and wells is, for the most part, impregnated with carbonic acid, which imparts to it the agreeable taste it possesses. Exposure to the air, for some time, is

found to deprive it of the greater part of this gas, which, it is generally supposed, has been dissipated in the air. But, since water, at its mean temperature and pressure, is capable of holding its own volume of carbonic acid in solution, the loss must be ascribed to a different cause. In the water which runs from springs, there may be observed a kind of green slime, the production of which does not appear to be, in any manner, connected with vegetation. This is carbonaceous matter, formed by the decomposition of the carbonic acid contained in the water. Its quantity appears increased, as the water is more strongly impregnated with carbonic acid, or subjected to circumstances which promote rapid evaporation; a fact which leaves no doubt respecting its origin.

17. A similar deposit may be observed in streams, at those places where evaporation takes place with great rapidity—as on mill-dams and water-falls—where it is accelerated by the agitation of the water and the dashing of it into spray. A great part of the carbonic acid, thus decomposed, is derived from the air. In observing the course of rivulets, I have often been struck with the fact, that the greatest quantity of this carbonaceous matter is deposited in places where the water tumbles over rocks, and suffers the greatest agitation—places, indeed, very unfavorable for a deposit of any substances dissolved or suspended in water, and still more unfavorable for the reception of seeds. This proves that the formation of the substance is due to evaporation, the continuation of which produces insolubility, and causes it to be deposited in places where it occurs. It may, perhaps, serve as a food to fishes; and the Confervæ, which are found attached to rocks in running streams—if they are to be regarded as plants—derive their food from the same source. The formation of the compound known by the name of Crenic and Apocrenic Acid, Humin Geine, &c., which are found in springs, owe their origin to the cause I have explained, and may be considered modifications of the same substance.

18. Every attentive observer of these, and other facts, may readily conceive that the decomposition of carbonic acid, which must result from the continual evaporation from the surface of the earth, is quite adequate to form all the humus or vegetable mould of the soil, and to supply the waste attending vegetation. On marshy, wet lands, where this process is seldom interrupted, the greatest quantity of carbonaceous mould* generally occurs. We should, no doubt, find the fertility increased in the same proportion, if the continual evaporation did not render the greater part of this mould insoluble, diminish its tendency to decomposition, and thus impair, or perhaps, destroy its fertilizing

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* The term carbonaceous mould, and other terms applied to this peculiar substance, are not intended to convey the idea that it consists entirely of carbon. It also contains a large portion of oxygen and hydrogen. Its formation may be supposed to consist in the union of carbonic acid and water, with the separation of a large portion of oxygen. Whether this oxygen is derived from the water, or from the carbonic acid, is a question which might appear difficult to be decided. But the fact, that oxygen and hydrogen occur nearly in the proportion in which they form water, must lead us to suppose that it is derived from the acid, though in many instances the water also undergoes decomposition.

properties. In this condition, it may be considered the same substance which Thaer designates Sour Humus. I shall afterwards shew how the fertilizing qualities may be restored by culture, and by the application of various manures to the soil.

19. In the same manner we may account for the formation of peat, which occurs so frequently between the 40th and 60th parallels of latitude, in situations where there is an excessive quantity of water in the soil. The continual evaporation tends to decompose carbonic acid—to precipitate it from the air, and to render it capable of resisting future decomposition. If it is absurd to ascribe the formation of humus to vegetation and decay, it is no less unreasonable to suppose that these causes could produce the immense quantities of peat which sometimes occur on the surface of the land.

20. To produce decisive evidence in regard to this theory, I must state a few facts respecting evaporation, which have been established by the experiments of Bict and Dalton. The quantity of water which a certain portion of air holds in solution, depends on the temperature; and an increase of heat will be attended with the formation of an additional quantity of vapor. On the contrary, a reduction of temperature will cause part of the vapor to assume a liquid form, and will thus increase the dryness of the air. For this reason, winds from the north are rendered comparatively dry, on account of the reduced temperature of the regions from which they blow; and, consequently, have a great evaporating power when they arrive in southern climates, on account of the accession of temperature which they receive. Winds blowing over a continued tract of land, or coming from a mountainous region, must possess this power—perhaps in an equal degree—while those blowing from the south, or over large bodies of water, are generally loaded with moisture, and attended with rain.

21. This may account for the fact that, in Europe the accumulations of peat, to which I have alluded, are seldom found on the southern or western sides of a mountain, but generally occur on the northern and eastern sides—the wind from the latter points having greater evaporating power, and causing a more copious precipitation of carbon from the air. Trees, for the same reason, are covered with moss more frequently on the northern than on the southern side—as the northern winds cause the fixation of more carbonaceous matter from which the moss receives nourishment. Even in the elaboration of the sap by the leaves, the influence of the northern winds is perceptible in some degree. A number of measurements which I made on the trunks of trees, generally indicated a more rapid growth on the northern than on the southern side; and I have been told that the wood, on the former side, is usually preferred on account of its strength and durability.

22. The air, at the surface of the earth, being much warmer than that in more elevated situations, must have a greater power of evaporation; and this power is increased by the partial absence of vapor, which, as it is formed, ascends to the higher regions of our atmosphere, leaving the air at the surface in a comparatively dry state. On account of the excessive cold, and the constant influx of vapor to those elevated regions, evaporation is almost entirely suspended, and the

condensation is continually going on—except when a descending cloud meets a warmer atmosphere, when a slight evaporation will take place, and the moisture will disappear. In like manner—(strange as it may at first appear)—evaporation takes place very rapidly during a shower of rain—as the drops of water descend through the dry air at the surface of the earth. The accession of temperature which they receive, their swift motion, their attrition against the air, their division iuto minute particles when dashed against the ground, must offer favorable circumstances for the formation of a copious quantity of vapor. From what I have stated, we should conclude that a large quantity of carbonic acid should be decomposed; and that the carbon should gradually separate from the atmosphere, and fall to the ground. Thus, the fall of rain must always be attended with a diminution of carbonic acid; but I shall afterwards shew how it is again restored to the atmosphere. It may be observed, that the disappearance of this gas, after rain, has been proved by the most accurate experiments; and some suppose that it is absorbed by the water. This opinion has led to the conclusion, that the greater part of this gas, so essential to vegetation, must be soon permanently withdrawn from the air, by the waters which cover such an extent of the earth's surface. But this last theory, which conveys such dismal intelligence to the human family, is at variance with the constancy observed in the mean qnantity of carbonic acid in our atmosphere; a constancy which could not be maintained by the comparatively small portion of it which issues from carverns—nor by the irregular supplies ejected from volcanoes.

23. It has been discovered by experiments made by Saussure, with the greatest care, that, on tho tops of mountains, the quantity of carbonic acid is greater than in vallies; and that no diminution is observed after rain. These facts also refute the opinion, that its absence, after rain, is due to absorbtion—(as it should also be absorbed on mountains)—but they accord exactly with the theory I have explained. As the rain, in descending from the clouds to the mountain, receives little accession of temperature, and meets with no dry air, evaporation is, in a great measure, suspended, and no decomposition of carbonic acid takes place. As the gas sustains no material waste, it must always exist in abundance, and in the same quantity. These phenomena cannot be satisfactorily explained on any other principle; and nothing is more repugnant with reason, or the law of physics, than the opinion of Graham, who supposes that the oarbonic acid, at high elevations, was derived from volcanoes, and is retained, (by some unknown force), at the elevation to which it was first projected.

24. Perhaps it is owing to the absence of evaporation that, notwithstanding the increased supply of carbonic acid on mountains, trees grow to a less size than in vallies; a fact ascribed, without sufficient reason, to the diminution of the atmospheric pressure. In viewing, from the summit of a mountain, lands under proper cultivation, and without any deficiency of moisture, I have often observed that the blackish hue, which indicates the presence of vegetable mould, diminished as the land was more elevated. The existenoe of this mould was evidently due to the decomposition of carbonic acid by evapora-

tion, which proceeded more rapidly, and produced a more copious formation of mould in the vallies, than in more elevated places.

25. In those places where carbonic acid is exhaled from the ground, notwithstanding its injurious effects on plants in the vicinity, it has a beneficial influence on the vegetation of the surrounding lands. In the valley of Gottengen, it rises from the earth in a considerable quantity; and, on the surrounding hills, vegetation commences sooner, and proceeds more luxuriantly than in other places. Yet, the most impartial experiments prove that carbonic acid, instead of being a food to plants, is very injurious to them, when any increase is made to the quantity already in the air. Such facts have long been the source of much controversy, and of inexplicable difficulties to theorists; but these difficulties must vanish, when we suppose that this gas is decomposed in the atmosphere, and transformed into humus for the nourishment of plants.

26. As volcanoes have been so frequently refered to by chemists as sources of carbonic acid, I will endeavor to give an explanation of their eruptions, which I hope will be as satisfactory as any I have yet met with. Without dwelling on the supposed existence of a central fire, the condensation of gases, or the oxidation of metals, which have been vainly advanced by geologists, to explain the intermitting nature of these phenomena, I shall merely consider what should take place in an enormous abyss, extending from the regions of perpetual snow, to the lower and warmer places beneath the surface of the earth. The air which enters the crater must be nearly deprived of all moisture, by the cold to which it is subjected. When it reaches the bottom of the volcano, and partakes of the increased temperatnre of this region, it must have great power of causing evaporation. The presence of water at the bottom, must give rise to the formation of vapor; and this operation must continually go on, by reason of the circulation of the air within the volcano—the moist air ascending, while the dry air deecends to supply its place. Such a rapid evaporation must cause the decomposition of the carbonic acid contained in the air and in the water, and the deposit of a large portion of carbon. I have before alluded to the presence of carbonic acid in springs and wells, and, as it will be afterwards shown that the quantity dissolved in water, depends on the depth to which it penetrates beneath the surface of the earth, or the pressure to which it is subjected, water at great depths of the sea must contain it in abundance. Sulphate of iron, also, which occurs so frequently below the earth's surface, must be dissolved by the waters which penetrate to the bottom of the volcano, and will be converted into sulphuret of iron, on account of the deoxidating power of evaporation. The deposit of these substances, and of other compounds of sulphur and of carbon, is quite adequate to supply combustible matter for volcanic eruptions. These terrific events may occur whenever the supply of water is exhausted, combustion being being promoted by the increased temperature peculiar to subterranean regions.

27. To return to the formation of humus; I will adduce some more examples to show that it is formed by the decomposition of carbonic acid in the manner I have described. In some lands, if the subsoil,

which contains no vegetable mould, be spread on the surface of the ground, and exposed to the influence of the air and moisture, it soon acquires the properties of vegetable earth, and is equally beneficial to vegetation. In volcanic districts, vegetable mould has been formed in the same manner over the lava which had been ejected from the volcano, and which, says Liebig, "cannot contain the smallest trace of vegetable matter." Lands, too, which have been in an exhausted condition, are rendered productive by being allowed to remain one or two years in fallow—vegetation being completely checked by plowing, and by other means of culture. On the sandy islands recovered from the sea, a gradual formation of vegetable mould takes place, and renders them capable of supporting the wants of vegetables, of animals, and, finally, of man.

28. In these instances, the organic matter of the soil is derived exclusively from the atmosphere—not from the decay of plants. To account for the beneficial effects fallowing, Liebig supposes that the soil is, by this means, replenished with certain inorganic substances, which are removed by many crops. But it does not appear that crops exhaust the soil, in proportion to the quantity of these ingredients which they contain. Other writers, with less judgment, ascribe it to the influence of the air; while, at the same time, they maintain that the nitrogen of the air, does not enter into any vegetable compound; and that oxygen only promotes the formation of carbonic acid at the expense of the carbon of the soil; and, consequently, tends to exhaust it. Consistently with the opinions generally upheld by Agricultural Chemists, nothing could be more injurious to the land, than to waste the humus in this manner, without giving any nourishment to crops.—Such views first gave rise to the anti-fallowing mania, which prevailed at the commencement of the present century; and which, for some years, has generally subsided. Many still suppose that a proper succession of green crops would prevent the necessity of fallowing, and be infinitely more beneficial to the land. But whatever may be the success of this course on the richest lands, practice does not appear to recognise the propriety of pursuing it on lands of moderate fertility. "It is not," says Loudon, "because turnips, cabbages, &c., will not grow on such soils, that a fallow is resorted to, but because, taking a course of years, the value of the successive crops is found to be so much greater, even though the unproductive year is interposed, as to give a preference to fallowing."

29. A deficiency of vegetable mould, generally occurs in dry soils, chiefly because evaporation is often suspended from a want of moisture; but this mould contains little sour or coaly humus, so peculiar to marshes. For this reason, the fertility of the soil does not diminish in the same proportion of the supply of humus. The deficiency is also compensated, in some measure, by a difference in the chemical composition arising from a union of a portion of hydrogen. During evaporation, a small portion of of the water is decomposed, and its hydrogen enters into combination with the carbon of the soil, or with the products of vegetation. This must be naturally expected to take place when the supply of water is scarce; as a partial decomposition must

result from the tenacity with which a small quantity of it is retained by leaves and other substancs. It is not surprising, therefore, that vegetable compounds which contain the greatest amount of hydrogen—as oils, cacutchouc, &c., should be peculiar to dry and warm climates. In England, hazel-nuts would scarce yield oil enough to pay the labor of extracting it; while half their weight, in oil, may be extracted from them in the south of Europe. The presence of hydrogen gas in the soil, may serve as a good test for the quality of the mould, as it shows that it contains little sour or coaly humus. Indeed, Arthur Young and Priestly, in analyzing vegetable earth, found that the quantity of hydrogen they obtained, was in proportion to the fertility of the soil.

30. Having shown the manner in which humus is formed, my next object is to consider how it imparts nourishment to plants. The decomposition of carbonic acid, by the leaves of plants, to which I have before alluded, has led many modern writers to suppose that this gas alone is the proper food for them; and that humus must be changed into carbonic acid, to support vegetation. This doctrine is not, however, sustained by experimental proof. Plants die very soon in an atmosphere of carbonic acid; and are materially injured by a quantity of it too small to exclude any appreciable portion of oxygen. Its injurious effects may be observed on the low and stunted vegetation in cities, and public places; but it is more clearly perceptible at those places where it issues from the earth, and where vegetation appears checked, as the supply augments. The opinion of its nutritive qualtity, when applied to the roots, is equally untenable. Young plants, vegetating without mould, lived longer when pure water was applied to them than when the water was impregnated with carbonic acid; and it is found, also, that spring-water which contains it in the greatest quantity, is least beneficial for irrigation. Indeed, if carbonic acid were a food for plants, burned lime would be very injurious to their growth, by withdrawing this gas from the soil, and withholding from them their proper nutriment; yet it is extremely fertilizing. And, though a partiality for this theory gave rise to the opinion, that carbonate of lime was much more beneficial to the land, and mills were constructed for the purpose of pulverizing chalk and limestone, yet it was found so much inferior to burned lime, that the practice has been discontinued.

31. The common practice of using organic manures, in a fermented state, was condemned by Davy, a zealous advocate of the theory. He recommended that they should be used as fresh as possible; that in fermenting, they might yield a copious supply of carbonic acid to the plants, and might sustain no waste. But his opinion was proved to be erroneous; and the process he recommended has been, after a fair trial, entirely abandoned by practical farmers. If carbonic acid afforded nutriment to the leaves, in its gaseous form, the humus, in emitting it, must sustain a loss which could not be repaired by vegetable decay. If it dissolved in water, and ascended through the sap to the leaves, it could never afford sufficient nourishment for most crops. Liebig calculates that the rain, which falls on the land, could not dissolve enough of humate of lime to furnish the carbon usually contain-

ed in crops. But it is easy to show, by a similar calculation, that the quantity of carbonic acid,which this water holds in solution, is far from being adequate to the same purpose.

32. I shall next show that all the changes which take place in the vegetable kingdom, can be reconciled with the theory that the solution of humus in water supplies nourishment to plants, by being absorbed bp the roots. It must, however, be observed, that all humus does not occur in soils in a soluble state ; but, by excessive evaporation, some is transformed into sour, or coaly humus, which is almost insoluble in water. The opposite effects, however, are produced by the condensation of vapor ; and humus is restored to a soluble state by this means, and, also, by condensation in general, which gives rise to positive electricity. For this, the power with which the soil absorbs moisture, offers favorable conditions ; and, it is a fact, stated by Davy, Loudon, and Johnston, that this absorbent power is generally proportional to the value of the land.

33. The presence of heat, and the absence of light, tend to promote the solubility of humus ; and hence, the advantage of placing such as is recently formed, a few inches below the surface of the soil ; where heat, but not light, can have access to it. It is evident, from a little reflection, that much benefit might be derived from placing all at the same depth—neither too near the surface, nor too far from it. This is accomplished with the plough, more completely than by the spade ; and hence, it is generally observed, by practical farmers, that more luxuriant crops are produced by ploughing, than by spade husbandry, notwithstanding the more perfect manner in which the ground is pulverized by the latter method.

34. The humus is, in this manner, reduced to such a condition that it readily dissolves in water, and is absorbed by the roots of plants.—Even this absorbtion may tend, by an electrical excitement, to increase the solubility of the humus in the vicinity of the roots. Some experiments show that an intimate connection exists between positive electricity, and the principle which causes capillary attraction. But, without discussing this question minutely, I must observe, that absorbtion and condensation of this nature, tend to promote the solubility, not only of organic, but even of inorganic substances. Water can dissolve only a small portion of carbonate of magnesia ; but if this compound be exposed to the air, in a finely divided state, and allowed to absorb moisture, water dissulves fifty times the same quantity ; and even silex, under circumstances of a kindred nature, acquires solubility in a slight degree. No wonder, therefore, that the latter substance, notwithstanding its insolubility in ordinary cases, should be found so abundantly in the ashes of vegetables.

35. These operations, which are so generally taking place beneath the surface of the earth, must produce positive electricity at the roots of plants ; while evaporation must necessarily render the leaves and branches negatively electrfied. We must conclude, therefore, that a current of positive electricity is in motion from the roots to the branches of a tree—(if we adopt the theory of Dufay)—that a current of negative electricity must move in an opposite direction. These currents

cause the motion of the sap, by which the food of plants is conveyed to its proper destination. The experiments of Dutrochet seem to prove that the flow of the sap is due to opposite currents of electricity. The ascent is also modified considerably, by the expansion and contraction of the wood, resulting from a variation of temperature to which it is subject.

36. I must not omit to mention, that the continual condensation causes the decomposition of the soluble humus, and the formation of carbonic acid, and this is promoted by heat also. This kind of fermentation, as it may be called, has some influence on the flow of the sap. Instead, however, of causing the flow upwards, it is more reasonable to suppose that the descent is occasioned by it, and that, at only certain times—as it leaves the ground negatively electrified. In summer, the formation of carbonic acid proceeds very rapidly, while its decomposition is not so rapid—evaporation being often suspended for want of water. In winter the formation is frequently checked by cold, while the decomposition is going on through the influence of evaporation, which takes place at very low temperatures. Consistently with this theory, therefore, the least quantity of carbonic acid should exist in the atmosphere in winter, and the greatest in summer, or after a long continuance of dry weather. This inference is fully confirmed by the experiments of Saussure; experiments, no doubt, conducted with the greatest care and impartiality, as the result tended to overthrow a doctrine of which he was an advocate.

37. According to the opinion that plants alone consume carbonic acid, and purify the air; the least quantity should be in the atmosphere in the end of summer, and the greatest in winter, when the consumption of carbonic acid is suspended on account of the absence of the leaves, and the amount is increased to some extent by their decay. This theory, therefore, is directly opposed to well established facts; but this is not the only nor the greatest contradiction. The greatest quantity in 1000 parts of air is .62, the least .37. This shows a variation, in the course of a few months, 100 times as great as could be produced by vegetation or decay. It is absurd to attribute this variation to the circulation of the air, as this should cause it principally on elevated places, and on mountains, where, as I have stated before, no variation is observed. It is evident that we must look for these changes to some more abundant source, and this is presented in the electrical changes to which I have alluded.

38. The elaboration of the sap, or the conversion of humus into woody fibre, and into the various products of vegetation, is effected by the currents of electricity to which I have alluded. I have given instances of the effects of evaporation, in causing the fixation of carbon and increasing the insolubility and sclidity of bodies. We may readily conceive that it must impart solidity to the carbon, dissolved in the sap, which is only an extension of the principle called into action in the cases to which I have alluded. If we suppose this principle to be vitrious, or negative electricity, we should conclude that its effect is not confined to the leaf, but must be communicated to all parts of the trunk of the tree, on account of the conductieg power of the wood,and

convert the dissolved humus into woody fibre. Nature appears to have designed the leaves for the special purpose of the elaboration of the sap; but instead of conveying it to them, and again transmitting it, in its altered state, to the various parts of the tree, she has adopted a more simple and effectual method for accomplishing the same purpose. The evaporation from the leaves, gives rise to the excitement of negative electricity; and this, through the conducting medium of the fibres, or the moisture they contain, tends to consolidate the sap, causing, perhaps, at the same time, a slight deoxidation. In spring, when the leaves are absent, and evaporation is almost suspended, the juice of the maple affords sugar. In April, when evaporation begins to take place to some extent, from the newly formed leaves, the gradual conversion of sugar into woody fibre, is marked by the viscidity of the syrup. During the summer, when great evaporation takes place from the leaves, there is a continual formation of woody fibre. In the end of autumn, the formation ceases, and the presence of sugar can now be recognised in the sap. I shall now consider more minutely the manner in which these changes are effected, all of which can be traced to the influence of electricity.

39. It appears, from a chemical analysis of starch, gum, sugar, and the cellular fibre of wood, that they are all composed of the same elements, united in nearly, or, perhaps, exactly the same proportions.—The atomic composition of each, may be represented by the formula C.12, O.10, H.10; and woody fibre differs little from them in composition, containing less oxygen and hydrogen. Several parts show that these substances are mutually convertible into each other; and sawdust has been actually converted into starch, by either of the following methods: 1st. by being heated several times in a baker's oven. 2d. By the action of strong sulphuric acid. 3d. By the action of hydrate of potash. In the first method, the change of the sawdust seems due to the absorbtion of vapor from the air, on account of its capillary attraction. In the second case, the conversion is attended with no decomposition of the sulphuric acid, and is caused by the absorbtion of moisture from the atmosphere, by the condensation experienced in its union with water, and by its electrical state, to which I will shortly refer. In the third, the change may be traced to the condensation of vapor; and, perhaps, of carbonic acid, which potash absorbs from the air. It may be observed, also, that starch or sawdust may be converted into sugar by the action of sulphuric acid; and the change appears to depend on the same principle of condensation—or positive electricity. Potash and lime appear to act in like manner, in the purification of sugar, as it has been shown, by M. Pelouze, that the carbonic acid which the lime absorbs, is principally derived from the atmosphere. On the contrary, the deterioration which sugar suffers, when the evaporation of tne syrup is conducted at a low temperature, or in the open air, seems owing to its partial conversion into starch, or woody fibre; and a change of the same nature is apparent, when the extractive matter of vegetables is rendered insoluble under similar circumstances.

40. Sugar, vegetable extract, starch, gum, and woody fibre, may be regarded as the same vegetable matter, in different states of electrici-

ty; and, therefore, in different degrees of solubility. The production of sugar is owing to the influence of positive electricity; and its solubility and tendency to decomposition, seems due to the same cause. The formation of woody fibre, its insolubility, and tendency to resist decomposition, must be ascribed to negative electricity, which, in the vegetable kingdom, proceeds from evaporation. When this takes place from the leaves, the substances dissolved in the sap, must gradually pass into woody fibre. In the spring, before this change takes place, a portion of sap in the upper part of the tree, must ascend to the branches. From want of elaboration, it is highly charged with saccharine and extractive matter, and is expended in the production of flowers and blossoms, which, on this account, continually emit carbonic acid.—Blossoms are sometimes observed to return in autumn, from the partial suspension of evaporation, but in a small number, the supply of sap being exhausted during the summer. Flowers, indeed, occur at other times, on many small plants, on which the action of the leaves is not adequate to the complete elaboration of the sap during the short time it takes to ascend; and the same cause might give rise to the imperfect formation of woody fibre in weeds and smaller plants, and to their want of strength and durability.

41. As it might be inferred from what I have stated, that the sap and the wood of all large trees, should be necessarily the same, I shall proceed to point out causes from which these differences might arise.—If, for instance, it be asked, why should the sap of some trees yield sugar, and some substances which are absent from others? An answer might be given by considering the relative influence of the bark, the leaves, and the climate. Sugar, and other saccharine compounds, when dissolved in water, readily pass through substances which are impervious to other solutions. Is it not reasonable to suppose, that trees of a dense and firm bark round the roots, will admit these saccharine solutions to the exclusion of many others? These, when converted into bark, and woody fibre, must, in turn, partake of the texture and hardness of the first bark, on account of its homogeneous nature, and thus, will ensure a continuation of the same formations. The substaces thus excluded, accumulate at the roots, and may, perhaps, be what have been called "root secretions," which have occasioned so much controversy among chemists. They may, indeed, be rendered capable of assimilation, by the means to which I have alluded—especially by the absorbent power of the root, which may tend to dissolve, and to impart saccharine properties to them.

42. On the other hand, trees of a soft and porous bark, afford a more indiscriminate admission of the various substances presented to their roots in solution; and, consequently, the sap affords little saccharine matter. The consolidation of the sap must give rise to the formation of bark, and woody fibre of the same porous nature; and the diminished capillary power of the roots, will be less effectual in converting the humus into saccharine matter. These views are conformable with observation. The maple, the hickory, and other trees of a hard and dense bark, afford sugar; and this compound is partly absent from other trees, as the firm texture of the bark diminishes. It is difficult to

determine, with accuracy, the quantity of sugar contained in trees, as some may be formed during the analysis necessary for this purpose. But certain facts will guide us to an estimate sufficiently correct, as the presence of sugar in wood promotes speedy decay. As trees of a firm bark are generally most liable to decay, we may infer that they contain it in a considerable quantity. On the contrary, the great scarcity, if not the total absence, of the saccharine matter—in trees of a porous bork—is indicated by their great durability, when exposed to air and moisture, notwithstanding the porous nature of their wood. It must, however, be considered, that these effects are modified, in some degree, by the influence of the leaves, and the climate.

In the elaboration of the sap, it may be imagined, that whatever be the size of the individual leaves, their effects should be proportional to their united surface. However, though the amount of water evaporated, be in proportion to the extent of the foliage, the imperfect conducting power of the leaf, prevents the electrical excitement—or the elaborating power—from increasing in the like proportion. A great number of small leaves are far more effectual for the elaboration of the sap, than a number of larger ones comprising the same superficial extent. In this respect, an analogy might be shown to exist between the leaves of a tree, and the plates of a galvanic battery; and, according to the usual theory, on Galvanism, I have attributed the effect to an imperfect conducting power. In a future essay on the connection of heat, light, and electricity, I intend to discuss more fully the primary causes of these phenomena.

44. The elaboration of the sap must not be confounded with the decomposition, by the leaves, of the carbonic acid, contained in the air around them. It may be asserted, that plants, in the manner in which they derive their carbon, exhaust the soil, to a great degree, of the vegetable mould which enters into their composition. Still, they afford, in turn, a considerable portion of carbon to the soil, not only by their decay, but by the conditions they afford for forming humus from the decomposition of carbonic acid. The water being received by their leaves, evaporation takes place much more rapidly than from lands destitute of vegetation, on account of the greater extent of surface presented by them to the air. More carbonic acid is, therefore, decomposed, and more carbon falls to the ground to replenish the humus.—Trees, whose leaves and branches ascend high into the air, contribute to these effects in a very great degree, and, consequently, cause a continual increase of the supply of humus, while several other vegetables tend to exhaust it. A crop of hemp does not exhaust the soil so much as one of flax, though it draws the same ingredients from the soil, and in a greater quantity; but its higher and more extended foliage must cause a greater accession of carbon to the soil, on the principles I have explained.

45. Indeed, most of the effects of plants, in exhausting or enriching the soil, which are generally attributed to the removal of inorganic ingredients, may be traced to the contending influence of their leaves and their roots. The former, by their capillary power, render the humus soluble, and appropriate it to food of plants; the latter are em-

ployed in its elaboration, and prevent any waste of the supply; while they also tend to precipitate more carbon from the air to the ground.—The effect of the former in producing carbonic acid, is apparent in the growth of the fungi, while the absence of suitable evaporation, to effect its decomposition, cause them always to emit carbonic acid; and it is observed, indeed, that the fungi impoverish the soil, in a very great degree. Some experiments, which I have been lately engaged in performing, will, I trust, when completed, show the effects of the adhesive power of the leaves of different plants; and will lead to a most accurate estimate of their power of exhausting the soil.

46. As the elaboration of the sap is chiefly dependent upon evaporation and light, the length of the day is very favorable for the production of woody fibre, while the length of the night, with a suitable temperature, must promote saccharine formation. In high latitudes, the days in summer being much longer than the nights, the formation of woody fibre takes place with great rapidity, and in great perfection.—Tropical climates, where the days and nights approach nearer to an equality, are not so suitable for the production of woody fibre, but afford sugar in a greater abundance. In northern latitudes, sugar, starch, &c., appear to be formed in autumn, when the days and nights are nearly the same length; and, to these formations, the ripening of fruits, about this time, may be ascribed. The diminished solidity of the leaves, from the same cause, and from the waste of carbon, which is converted into carbonic acid, cause them to fall from the tree at this time. A minute explanation of the ripening of seeds, their germination, and the effectual manner in which they produce plants of the same species as those on which they grew, shall be deferred till my next essay.

47. An imperfect elaboration of the sap, (as should be inferred from the principles I have explained,) may proceed from a want of sufficient evaporation, from an undue condensation of vapor, or from the excess of positive electricity in the atmosphere. Such a defective state of elaboration, should necessarily impart to the various products of vegetation, a tendency to undergo decomposition. I have, indeed, little doubt, that the potatoe-rot, which has extended its ravages over various parts of Europe, and has visited some parts of this country, may result from the electrical state of the atmosphere, or from some other sources of electricity. No wonder that the application of lime, potash, salt, &c., were ineffectual; and, perhaps, only served to accellerate the decay. When evaporation is caused to too great an extent, the formation of woody fibre takes place in excess; and the products of vegetation have a greater tendency to resist decomposition, a less nutritive power, and a less disposition to germinate. In the last case, the application of lime may be productive of some benefit; while in the former case, it is evidently injurious. The fact, that the diseased potatoes—(according to the analysis of Ure)—contained an unusual quantity of sugar—that they had a very great tendency to germinate, and that drying them by direct exposure to the sun's rays, was the best preventative, seems to accord exactly with the present theory. Indeed, I have no doubt that most of the diseases of plants can be traced to the undue influence of

positive or negative electricity, which act such an important part in the material world.

48. Though salt-water is converted into vapor more slowly than fresh, when exposed to the air, yet we must suppose that at sea, evaporation may cause the decomposition of carbonic acid; and much carbon is also precipitated from the air during rain. To show the means employed by nature for restoring this carbon to the atmosphere, it will be necessary to dwell upon the effects of the condensation of water, by the great pressure to which it is subjected at great depths. This condensation is a fertile source of positive electricity, and, with the absence of light, promotes solubility, and the formation of carbonic acid from organic matter. The carbon which is precipitated from the air, as it descends through the water, gradually increases insolubility, and finally passes into carbonic acid. The oxygen, combined with the water, is expended in this operation, and the water is replenished by the air which the water absorbs, and by the tendency of this air to diffuse itself equally through the water. The great pressure and condensation, and not only favor the production of carbonic acid, but also tends to dissolve it, to a great degree, in water. In this manner, the organic matter is reduced to a state of solution in the water; and even the vegetable mould, brought down by rivers, and imbedded in the sands, is gradually converted into carbonic acid, and transferred from the water to the atmosphere, and finally to the soil, to perform, once more, some important office in the growth of vegetables.

49. The quantity of carbonic acid which salt-water could absorb, would be soon withdrawn from the atmosphere, and permanently retained, without any increase or diminution, were the absorbent or dissolving power of the sea subject to no variation. Under the same circumstances, the carbonate of lime, dissolved in sea-water, would receive no increase, nor be diminished by depositing the material necessary for snbmarine formations. But the depths of the sea, on account of the great condensation, are in a state of positive electricity, which, as I have proved before, is the great agent in promoting the solution of bodies. This gives the water, at great depths, a capacity for holding a large quantity of carbonic acid in solution, and also a considerable quantity of carbonate of lime. The agitation of the sea during storms, or any other cause which could change the local position of the waters, in elevating them to the surface, must cause the evolution of a large portion of the carbonic acid, which the diminution of pressure has rendered the water incapable of retaining. A portion of carbonic acid is, therefore, transferred to the atmosphere during these commotions, but at other times it is regained from the atmosphere; and this, perhaps, causes the diminution of carbonic acid, which has been observed in the sea, and on large bodies of water.

50. The carbonate of lime, which is afforded by the calcarious rocks, at the bottom of the sea, and dissolved by the water in consequence of the great pressure, and the electrical state of these places, is deposited, when it rises nearer to the surface—when the water, changing its electrical state, loses part of its dissolving power. This deposit of lime

gives rise to the formation of coral, and other rocks, at the shallow parts of the sea. This forma.ion is commonly believed to be the work of a species of insects, which are found inhabiting these, and perhaps, derive subsistence from some carbonaceous matter precipitated in the manner I have described before. I shall not refute the idea that they form habitations from the lime thus deposited, but nothing is more absurd than to suppose that they either create the lime, or transport it from such immense distances to form their habitations.

52. The waters which penetrate through the depths of the earth, on account of the great pressure and condensation which they undergo, contain an excess of carbonic acid, with a portion of lime and other substances in solution. The solution of carbonate of lime, and is generally ascribed to the excess of carbonic acid, but why may we not, with equal propriety, suppose that the excess of carbonic acid was due to the presence of the lime? The presence of both, indeed, are evidently due to the same cause—and when this is taken away by the removal of the pressure, the lime is precipitated, and the excess of carbonic acid either assumes a gaseous form, or is decomposed by the agent to which I have alluded.

52. When treating on the formation of humus, from carbonic acid, I forgot to notice the changes which should take place in in accordance with the doctrines of galvanism. I shall now show that all the effects of evaporation, in causing the decomposition of carbonic acid, the fixation of carbon, &c., are precisely such as should necessarily follow from the laws of electro-decomposition, as established by Faraday and others. All compounds have been decomposed by galvanism; and,in the decomposition of the acids, it has been observed, that oxygen, clorme, &c., are always liberated at the positive wire; while sulphur, carbon, and the other bases, go to the negative. According to Faraday, the wires have no attractive or repulsive properties, but merely act as conductors of the electric fluid.

53. Now, it is proved satisfactorily, that when evaporation takes place, the surface at which the vapor is formed, is in a state of negative electricity—the vapor itself being positively electrified. As the vapor may act as a kind of conductor, we may now ask: what should be the effect of this electrical excitement on the carbonic acid in the water, and in the surrounding air? Must we not suppose that a decomposition should take place—and, if we adopt the principles of Faraday, that the oxygen should go off with the ascending vapor—the positive electrode; while the carbon should seek the place where the vapor was formed—the negative electrode? It follows, therefore, as a necessary consequence, that, as evaporation takes place from the ground, from fhe leaves of plants, from the descending drops of rain, that carbonic acid should be decomposed, and the carbon retained at or near the place where the vapor was formed. I say *near*, as the imperfect conducting power of the vapor may prevent the electricity from being concentrated at a certain focus, or accumulating there the carbon which was separated. It may be said, that the electrical excitement by evaporation, is very feeble; and, perhaps, inadequate to this decomposition; but, in the material world, all forces, however minute,

must produce their effect, and this decomposing force must accomplish, on a small scale, the decomposition of carbonic acid, and the gradual accumulation of humus.

It is not a little surprising, that modern philosophers, who have paid so much attention to the decomposing agency of electricity, and who have observed so diligently the electrical changes in the atmosphere, should have neglected to examine the chemical decomposition which must necessarily result from them.

The variations observed in the electrical state of the atmosphere, by night and by doy, during rain and in cloudy weather, at high and low places, all accord with the theory contained in the preceding pages; in regard to the excitement of negative electricity, by evaporation, and the decomposition of carbonic acid. Indeed, so far as I can learn, there are no phenomena in the vegetable kingdom, which cannot be traced to the influence of that universal chemical solvent—electricity. In another essay, I shall trace to this principle, the beneficial effects of organic and inorganic manures; the injurious effects of several substances to plants; the production and ripening of fruit; the germination and growth of seeds, &c.

The foregoing is a brief outline of the system of Vegetable Physiology, which I offer to the consideration of the public. I have omitted many proofs which might be advanced, to show that it is well founded; and I have left unnoticed several phenomena which it might account for in a satisfactory manner. I did not intend, in this little work, to render it free from all objections—to which a new theory must be subject; nor to answer all the arguments which may be urged against it. My object was to call the attention of scientific and practical farmers, to an examination of its principles; convinced, that by their researches, it may be fully confirmed; that it may be freed from the errors which have escaped my notice; and that it might be rendered productive of much utility in the practice of agriculture.

In conclusion, I beg leave to tender my most sincere thanks to several of my friends, who have been kind enough to communicate to me much valuable information on agriculture, during the time I have been engaged in these speculations.

TAL PROOF

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