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STATE AGRICULTURAL S

Members of the Legislature, and of the Medical Society of the State of New-York, at the Capitol in Albany, February, 1848;

ON THE

FOOD OF PLANTS.

By Alex. H. Stevens, M. D.,

President of the College of Physicians and Surgeons, and of the Medical Society of the State of New-York; Vice President of the American Agricultural Association.

ALBANY:

PRINTED BY C. VAN BENTHUYSEN.

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ADDRESS.

Mr. President and Gentlemen :

A legislative hall is a fit place, and an assemblage of legislative farmers and of learned physicians a fit audience for a discourse on a subject pertaining to the occupation of the mass of the people, their constituents and their clients.

I know too well the single-heartedness of farmers, and have experienced too often the kindness of medical brethren to doubt, that a well intended effort of this kind, however humble, will be indulgently received.

I have ventured to hope, moreover, that the example of a medical man offering to his fellow-citizens the reflections of leisure moments on matters germain to his own studies, might not be without its influence upon younger members of the profession, whose education peculiarly qualifies them to observe and investigate facts in physical science, and to reason upon them with the caution indispensable to the right pursuit of truth.

The main design of the observations to which your attention is now invited, is to investigate the sources of the food of plants, and the mode in which it is applied to their roots.

It will be seen that a vast series of changes of position and form termed *physical ;* of composition termed *chemical ;* and if in connection with vegetable or animal life, termed *vital* is incessantly going on ; all concurring and harmonizing with one another to bring about the great result — the final end of creation — the fitting of the earth to yield subsistence to man in return for labor ; allowing the agricultural laborer like the strong man, to " rejoice in his strength ;" the intellectual farmer to find his happiness in the search after truth, and impress upon all a deep conviction of the wise and benevolent arrangements of creation.

Neither the written word of God, or the material universe (his created revelation) affords any ground for the belief that there ever has been any *second creation* of matter or that even a single particle of new matter has been called into existence since the beginning when all was made.

Of this matter then created, it is equally certain that not an atom has been lost or destroyed. What we see going on around us is change, incessant change ; change of place or of combination, and change only. Permit me to ask your attention to some of these changes.

Besides the myriads of worlds in the firmament visible to the naked eye, the telescope brings into view numberless others all *moving* on their axes and in their orbits, with a rapidity that defies conception, and in perfect harmony. The loss of a single atom would derange the harmony of their movements. On the other hand, the microscope reveals movements *in small masses of matter* equally astonishing. The transparent web of a frog's foot, small enough to be covered by the cut end of a fine hair, exhibits in its circulating particles a degree of intestine movement which may be compared to that within the Exchange room in Wall-street at its busiest hour, to that of a legislative Hall at the time of dividing the house, or to a bee-hive preparatory to swarming. These are physical movements; changes of *place* merely.

Changes in the *composition* of the bodies called chemical changes, are going on, alike wonderful both in manner and degree.

Limestone is quarried to be burned to build houses and to enrich fields. In this process an air is separated which is food for plants. Besides this source of carbonic air, for so this air is called, millions of tons of coal are raised from mines, and being burned for steam engines, for culinary purposes, and on our social hearths, and also for artificial light ; are thus fitted to become a component part first of plants and next of animals. Large masses of wood and other vegetable matters are rotting on the surface of the earth. Animal substances are also undergoing decomposition, and rocks and earth are being dissolved. Thus carbonic acid, the wood gas, and ammonia, or the animal gas as it may be termed, and the mineral earths are supplied to become again parts of plants and animals, and each kingdom of nature gets back what it has given up. A tree is burned ; its particles are either dissipated in the form of air, or remain behind as ashes. The ashes return to the earth from which they were extracted ; the rest of the wood has been dissolved into gases, and both are fitted to become the food of future forests. The grazing animal while yet alive, supplies food to the herbage he feeds on; when he perishes, plants and animals alike feed upon his body.

When Major André was disinterred, nearly half a century after his execution and burial, "the roots of a peach tree," so says the official account of the British Consul "were found entwined among the bones of his skull." Of those here present, there may be some who have eaten of the fruit of that tree, and in whose bodies have thus become incorporated particles of matter that once formed a portion of the living frame of that gallant and accomplished soldier. Thousands of tons of bones from the battle fields of Europe, have been used to enrich the soil of England; and in our own country, many hundreds of Germans are employed in gathering bones for our corn lands.

The cast off bark and leaves of trees become decomposed, and afford nourishment to their roots. Every part of the animal body is in a state of perpetual change. The organic and mineral excretions an individual has cast off, even his breath may return to him no less than to others, and again become a part of his living body. The same matter forms the bodies of successive, and even of the same generations and individuals of the animal and vegetable kingdoms. Were it otherwise, the existence here of all living things would be limited. The materials necessary for their support, would ultimately be all consumed.

The results of *vital chemistry* are yet more wonderful: We inspire vital air, one source of which is the leaves of plants under the influence of the sun; we expire another air, carbonic acid, which is their food.

Animals are kept warm by a fire ever burning within them. The fat of their bodies is burned by the air inhaled into their lungs. The product of this combustion is the same as that of fat burned in a candle, viz: carbonic acid and water. If a man is struck down by a blow, or a poison or an apoplexy, so that he hardly breathes, his body becomes cold; the fire is almost extinguished. If he exercises or contracts a fever, he breathes more rapidly than usual, he becomes heated; the internal fire is increased.

If an animal is kept cold, it gets poor; its fat is consumed to keep it warm. You all know, gentlemen, the advantage of warm stables for your stock in winter. Perhaps some of you may not know the reason why large-lunged animals are fattened with difficulty. It is that they burn up their fat. Yet they are capable with proper feeding of becoming even fatter than others, because they keep their health and good digestion longer.

All living things are compounds of four elements :

1. *Oxygen* or vital air, a part of the atmosphere which supports combustion, rots wood, rusts metals, and turns cider sour.

2. *Hydrogen*, which with some of its compounds with carbon is a gas, and which burns with a flame, explodes in mines, (being there called the fire-damp,) forms burning springs, and with oxygen becomes water. On the inner sides of the glasses over the gas lamps in the streets of New-York, water formed by this union may be seen.

3. *Nitrogen*, a part of the atmosphere and a principal constituent of manure, and with hydrogen forming ammonia, otherwise called hartshorn. This is the product of animal decomposition, whether by burning or putrefaction, and it holds a relation to animal decomposition, not unlike that which carbonic acid does to vegetable decomposition.

4. *Carbon*, the residuum of wood where the hydrogen gas and its compounds have been burned away. Carbonic acid (carbon and oxygen,) is the gas which gives briskness to cider and to water, kills those who descend into wells in limestone localities, who sleep in close rooms where a charcoal fire is burning. Mineral springs and hundreds of volcanoes, some of them apparently extinct, and all breathing animals are constantly casting forth this gas. It enters largely into the composition of plants, and is discharged from them in the process of fermentation, of rotting and of combustion. In fine, it is wood dissolved in air. But there are some parts of wood, and some parts of animals which will not dissolve in air. These are what are termed the *mineral* portions in contradistinction to the former, which are called the *organic* portions. A log of wood is burned, some of it is dissipated in air, chiefly into carbonic acid gas ; a smaller portion, the ash, remains, differing somewhat in its nature according to the species of wood or vegetable consumed. When an animal substance is burned or left to decay, the organic portion in like manner is dissipated in the air in the form of hartshorn together with hydrogen, holding in solution sulphur and phosphorus. The other mineral or earthy parts remain. These are the bones, which are formed chiefly of lime and of phosphoric acid, the same which we smell after burning a loco-foco match.

The composition of plants and animals is the food they receive, deducting that which they cast off. No plant or animal creates any of the elements that enter into its structures. It only combines them into new forms. There is, however this great difference between plants and animals : Plants collect unorganized atoms, (matter not arranged in definite regular forms,) and build up from them their beautiful structures. Animals, on the contrary, receive their food from matter already organized ; the herbivorous animals directly, the carnivorous through the medium of the herbivorous.

The sea furnishes fish and guano, and thus renders back some of the nutriment washed into it in rain water falling upon it. What immense quantities must be washed into the sea by the Nile, the Ganges, the Mississippi, and the great rivers of South America, not of vegetable matters only, but of animal and mineral. These are the food of the animal and vegetable inhabitants of the sea. Some of these matters come back. In a certain sense, fishing boats and whale ships are manure boats no less truly than those which bring guano. Coal mines, volcanoes and limestone quarries, are immense manure beds. Thus the sea and the earth give back what they have received.

The changes of matter are three-fold : first from earth and air to the condition of plants, next to the animal creation, and lastly back again to earth and air.

In the various processes by which these materials are rendered available, there is a striking analogy. The rotting of manure in the ground may be described as a low, smothered, imperfect burning, much of the smoke or coal remaining behind. The smothered fire of a charcoal bed leaves still more of the coal unconsumed.

In the burning of peat in smothered fires, some ash is formed and the quantity of coal-like residuum is still less. When oil is burned or rapidly rotted, (if I may so say,) in a clear burning lamp, no soot, smoke or lampblack, (which is powdered carbon,) is left ; all is consumed, i. e., converted into carbonic acid gas and water.

The blacksmith sprinkles water on his coal fire, and stirs it up to make the coal rot faster. So, too, the farmer stirs up the earth to promote decomposition. The ship carpenter keeps his timber under water until he wants to use it, to prevent it from decay by securing it from the air, or he puts it under cover to keep it dry. The presence of both air and water is necessary for the rotting or slow combustion. When the old London bridge was being constructed, the remains of a former wooden structure built by the ancient Romans, were found unrotted. The farmer wets his manure heap, and turns it over to make it rot ; if it rots too fast he puts on more water to moderate the combustion, and prevent the carbonic acid gas, ammonia, sulphur and phosphorus from escaping. Deeply buried manure rots slowly, so do compact bodies of manure. The more slowly vegetable substances are decomposed, the greater the carbonaceous, coaly or sooty residuum. In preparing manure, heating and rapid decomposition should be carefully avoided, for by it is lost not only carbonic acid, the wood forming gas ; but also ammonia, sulphur and phosphorus, essential elements of animals and vegetables.

The aim of the agriculturist in the application of manure, should be, to make the period of its rotting coincide with the period when the crop wants the nutriment it furnishes in the act of rotting. Thus half rotted manure is preferred for potatoes, its greatest action being wanted for the tubers and not for the haulm.

Our social fires, whether of wood or coal, manure the atmosphere ; but it is wasteful to keep them burning when no one is present to enjoy them. It is equally wasteful to let manure rot in the ground or be washed away, when there is no crop to feed upon its gases or its salts. As manure begins to decompose the first moment it is dropped from the animal, so of course it immediately begins to lose some of its valuable qualities. It might be supposed, therefore, and Sir Humphrey Davy inclined to the opinion that it should be used immediately, either by putting under the earth or on the surface. But general experience is rather against the practice, at any rate the rule is not absolute. It is a question to be settled by careful observation, and not by scientific reasoning. But as it has been discussed theoretically, it may be right to say, that dung is valuable as manure: first, from the mineral ingredients it contains; second, from the ammoniacal compounds. Now these as are mostly formed in the manure by fermentation, and so far as respects them, the droppings of animals are no more manure, than an apple is cider, or barley is beer. Certain chemical changes must first take place, before the organic portion of the droppings is available. The case seems then to stand thus: If the farmer keep his manure, ammonia is escaping, and he thus suffers a loss; the rain is washing away the mineral salts from it. If he put it on the surface of his ground fresh, it dries, and the chemical change on which the formation of ammonia depends is partly prevented, and of the ammonia that is formed, much escapes in the atmosphere, instead of combining with the soil. If he plows it in fresh, it may be so separated that fermentation does not take place, for want of the requisite warmth, before the rain washes away the urea or principle upon which the formation of ammonia depends.

Now if we reflect that some soils are most in want of organic fertilizing principles, and others of mineral fertilizers; and secondly, that some crops require one or the other, and other crops both of these constituents of manure; and lastly, that some crops require a hot, and others a well decomposed manure, it must be allowed that the question is not to be answered without particular reference to the circumstances of each particular case.

The mineral food, or ash of plants, comes from the earth, rocks and stones; which are only solid earth, as earth is only crumbled, crushed or dissolved rocks and stones, and all are rusty metals, chiefly distinguished from metals properly so called, in the facility with which they rust. They are slightly soluble in rain water, which by combining with carbonic acid and ammonia, in its descent first purifies the atmosphere, and then enriches the soil. Who among us has not been struck with the grateful purity of the air after a fall of rain or snow. This is another striking illustration of the ordering of all things for our well-being.

The presence of organic matter undergoing decomposition, constitutes the difference between soil and earth. *Earth, when first brought to the surface, is barren*, incapable of supporting vegetation. A large portion of the globe was originally, or in remote periods in this condition.

In removing rocks from his fields, the farmer often brings to the surface masses of earth. These are barren, and remain so for years, unless manure is applied, and that too, liberally. Such earth is said to be hungry ; hungry it is, for the organic food of plants; for left to itself, its first act, if I may so express it, is to acquire carbonic acid from rain water, and ammonia from the same source, and from the atmosphere. These we have seen are the organic food of plants. It combines also with fœtid gases. These gases often contain phosphorus and sulphur, which are mineral food. Thus, if old clothes fœtid with ammonia, sulphur and phosphorus are buried in the earth, they are sweetened. The earth combines with these substances. So, too, if foul water from a wash tub is passed through earth, (and still more through charcoal,) it is purified, and the earth is enriched. Here is now another kind provision for the purification of the air we breathe and the water we drink.

The layers of earth near the surface chiefly appropriate the organic materials falling upon it.

As many animals live entirely upon plants, the materials of flesh and bone and whatever enters into the composition of their bodies must be contained in such food. How do plants get the materials by which they form flesh, bones and fat ? When an animal dies and is left on the ground, if not consumed by other animals, and the air be not (as in some parts of South America,) so dry as to convert it into a mummy, the soft parts of the body rise in the form of certain offensive gases, consisting of hartshorn with phosphorus and sulphur dissolved in hydrogen. It is this combination which gives to stale eggs and decaying teeth their intolerable fœtor and which blackens silver. All these matters are capable of and actually do combine with water and of course come back to the earth in rain water. The bones remain and after a great length of time crumble into dust. This is in fact animal ashes, the residuum after slow combustion, and like the ashes of vegetables came originally from the earth.

The sources of the organic food of plants, carbonic acid and ammonia, and with it of some portions of sulphur and phosphorus having thus been pointed out, it remains only to state that the mineral food, viz: potash, phosphorus and sulphur, lime, soda, iron &c., is found in the earth itself.

How the earth is fitted for vegetation.

Possessing mineral ingredients necessary in all cases, a very small capital of organic food, is enough for vegetation to start with. The first plant dying where it grew, leaves behind organic food collected and embodied from the air and water, and its successor starts with greater advantages. At length a forest rises on soil formed by the growth of centuries. The earth is now abundantly supplied with gases from vegetable deposits. The trees luxuriate in the riches bequeathed to them by a long line of ancestry.

When man with his axe and firebrand invades these solitudes, the gases, no longer appropriated by the trees and extricated with increased rapidity by the heat of the sun's rays, often prove fatal to him. What was food to them becomes poison to him. The harmony of nature may not with impunity be deranged. "The sound of the woodman's axe is the signal for the approach of death."*

Will my classical friends here excuse me for calling to their remembrance that the agency of the sun in generating disease by acting on vegetable and animal matters, is believed by many to be asserted in the allegory wherein Homer narrates the dire mortality of the Greeks by the Pythean Apollo?

Δεινὴ δὲ κλαγγὴ γένετ' ἀργυρέοιο βιοῖο.

The passage is beautifully translated by Cowper:

"Down from Olympus with his radiant bow the god,
And his full quiver o'er his shoulder slung,
Marched in his anger ; shaken as he moved,
His rattling arrows told of his approach.
Like night he came and seated with the ships
In view, despatched an arrow. Clanged the cord;
Dread sounding, bounding on the silver bow.
Mules first and dogs he struck, but aiming soon
Against the Greeks themselves his bitter shafts,
Smote them. The frequent piles blazed night and day."

* Rush.

It was Phœbus throwing his rays on multitudes crowded in a filthy camp.

The property in earth to combine with gases, is exhibited in the fact that animals buried therein are no longer offensive to the senses. The gases evolved from them (and into which except their mineral part they are resolved) are not imprisoned but combined with the earth. But the earth may become saturated, and then the gases escape, some portions go down with water rendering springs foul, and others rise and mixing with the common air render it unhealthy, unless plants are present to appropriate them. Hence the propriety of having grass or trees in grave yards. A tree and a fountain are also appropriately placed in connection, the fountain nourishes the tree, the tree purifies the fountain.

During a season of unusual health a valued connection of mine lost his life by a fever, contracted in overlooking a swampy field, long cleared, but then for the first time plowed up. The coarse grasses had before been sufficient to combine with the gases which the mass of vegetable matter covered by it and protected from the sun and air, had afforded. But under the double influence of the destruction of the herbage and the increased supply of gases consequent to tillage, the stirring up of the slow fire and closing the chimney flue, the noxious gases or malaria, as they are termed, being diffused in the atmosphere and respired, a fatal fever followed.

These gases when they rise from the earth combine with water in whatever form they meet with it. Hence the proverbial fatality of inhaling the moist air of the night in unhealthy localities, especially at the period of the first dew, for the heat of the sun by increasing the exhalation of gases from the surface renders that more highly charged. If we could suppose plants to be irritable like animals when they are taking their repast, one would imagine they would warn us to keep out of their way, to stay within doors, not to interrupt or rob them of any portion of their supper after they had borne the heat and burden of the day, and were thirsting for the rich dew of the evening.

Rocks by condensing water charged with ammonia and carbonic acid, become dissolved in it, and the solution thus charged with both the inorganic and organic elements is highly fertilizing.

A friend of mine owns a lot on the sound in Westchester county, which is known to have been used as a pasture and not to have been manured or tilled for forty years; probably never. The soil is a stiff clay, and a large part of it is covered with granite boulders and primary rocks. It is believed to be one of the best pasture lots in the county; the cattle and sheep not only thrive better, but the mutton is sweeter and the milk richer, than that which any other lot in neighborhood of highly cultivated farms affords.

Who that has looked at the granite tombstone, that marks the burial place of the regicide judge, Goff, in the New-Haven church yard, has not noticed how rounded off are the edges of the lettering; the stone has been dissolved by water. Moss also grows on their sides. The ashes of the moss contain phosphates, derived of course from the stone.

In northern latitudes, moss growing on rocks, is the principal, at some seasons, the sole food of the Reindeer; it must therefore contain phosphate of lime, and other mineral substances entering into the composition of his bones.

With a single remark further on the mode in which nature prepares food for plants, and I shall have finished this part of my subject.

The organic food of plants, is the same for all kinds whatsoever; though the quantities each kind requires vary greatly; on the other hand, the mineral food varies in kind as well as in quantity, and no plant can come to maturity in a soil wanting in any one of the various mineral ingredients that are found in its ashes.

Asking you to keep in mind that snow, rain and dew, bring carbonic acid gas to the earth, and ammonia also, and if flowing down the sides of rocks, mineral food too, I proceed next to show how dew is condensed, not only on the surface of the earth, but in all the cavities where air charged with moisture may enter.

Our countryman, Doctor Wells of South Carolina, was the first to explain the beautiful theory of the formation of dew: It is like the collection of vapor on a pitcher of cold water on a hot day; of the breath on the window-glass in a hot room in cold weather. The diffusion of heat is upon the principle of what may be termed "give and take." The human body is sending off heat as truly as a coal fire, and a living plant as truly as either; but of course in a lesser degree. If the plant receive heat from another body equal to that which it throws off, it maintains its warmth; clouds even reflect back heat. Hence there is no dew in cloudy nights. Absence of dew is therefore said to portend a storm. It only indicates the presence of clouds. But if the heat of plants is sent into space, as it is when the sky is clear, then they become cooled, and dew gathers on them. Dew never gathers on the bodies of animals, and it is not strictly correct to say, that dew is inhaled. What we inhale in a damp evening is water in the form of vapor; dew is water in the form of water. The dew drop on the petal of the lilly or the rose, is the tear of maiden innocence weeping in unrequited love.

I am tempted here to explain another meteorological occurrence, the nature of which is not generally understood: Before a storm, gases of unpleasant odour are perceived in the vicinity of low grounds, salt marshes, and foul spots on the earth's surface. These odours are said to portend a storm; in point of fact they do usually precede it ; the explanation is this: When the barometer falls, indicating that the weight of the atmosphere is diminished, the pressure of it on the gases existing in the soil being lessened, they rise as does water in a pump ; in popular parlance, they are sucked out of the earth and become thus diffused in the air.

Air in the earth is not at rest. When heated by the sun, it expands and part of it escapes: at night the earth becoming cooler it contracts again, and more air enters to supply the place.

In this RESPIRATION OF THE SOIL, carbonic acid and ammonia, and often sulphur and phosphorus are not only brought to it with water inhaled; but the oxygen of the atmosphere, and that double portion of it combined with water; which hastens the decomposition of vegetable matter in the soil and thus supplies more carbonic acid, itself the food of plants, and the preparer or solvent of their mineral food.

I close this part of my subject with the remark, that alternations of temperature during the day and night are as useful to plants as the alternations of the seasons.

Let us next consider in what manner water charged with organic and mineral food, is placed within the reach of the spongioles or absorbing extremities of the roots of plants.

In passing over a causeway raised above the tide water on my summer residence at Astoria, I perceived saline incrustations; this surprised me, and I concluded it had been overflowed; but afterwards having had half a barrel of impure sulphate of soda thrown upon the declivity of a compost heap which had been covered with loam, and looking at it after a rain followed by a drying wind, I observed that the salt had encrusted the surface extensively, and even gone *above the place it originally covered.* About this time passing near a manufactory of the ferro-prussiate of potass, I noticed that the refuse when first exposed to the weather, was uniformly black; but that parts of the heap which had been longer exposed, were covered with yellow saline incrustations. I was thus led to a train of thought that resulted in the following conclusion: Water falling upon the earth does not descend as in a leech-tub; some indeed goes down to form springs and rivers; for wells after a considerable time has elapsed, become impregnated both with saline and ammoniacal matters placed on the surface of the ground.

After water reaches the ground, it is subjected to the action of two opposing forces; gravitation which tends to take it down; capillary action promoted by evaporation, which tends to bring it up. In alternations of dry weather and moderate showers, the same water may ascend and descend many times before its ultimate destiny is settled; before it rises to form clouds, or descends to form springs. In each of these ascents and descents in the soil, it will acquire until saturated, new fertilizing matters, carbonic acid, ammonia, and mineral elements. These alternate movements are most active near the surface. They begin at the surface. The ascending current commences so soon as the evaporation commences and continues deepening its action in the upper layers, first arresting the descending current, and then altering its course to an upward one, and thus successively in each deeper stratum. In each ascent and descent, the roots of plants receive their food.

In long continued dry weather, the descent of water is arrested, or it may even ascend from great depths. A brick wall built on the ground, will draw up water many feet.

If these views are correct, it would appear that the mode in which rains and droughts succeed each other in particular climates and localities, has a most important influence on the fertility of the soil. In a series of years, the fall of water upon the earth may have been such as to carry down the fertilizing matters of the soil into the depths of the earth; or, on the other hand, to have brought them up from the subsoil, and concentrated them near the surface. Heavy showers would produce the first effect; moderate showers the second.

Long drought may thus enrich the soil by bringing up water charged with mineral elements from great depths, and beyond the region of ordinary supply. Hence the saying, " a season of great drought, is sure to be followed by an abundant harvest the next year."

The most ancient of the profane poets tells us of a wise old warrior named Ulysses, whose bow none but himself could draw; of another it is said that he attempted to drive the fiery chariot of Apollo and perished in the attempt. So to in our own times, poor Crafts tried to ride Eclipse in his contest with Henry, a feat for which Purdy alone was adequate. Should any of us attempt to alter the order of Providence, the failure would be equally signal.

Suppose for instance we had regular April showers all the year round, instead of the present alternations of heavy rains, and slighter showers and long droughts. What would be the consequence ? The water of slight showers would all rise in vapor. Of course springs would be dried up. In the next place only the superficial layers of soil would be available to the agriculturist, and this would soon be exhausted of its mineral food. Deeply rooted trees would die for want of nutriment to their roots. The cereal plants and vines and fruit trees would not ripen their products without dry weather to concentrate their mineral food. Gardeners imitate nature in the watering of hot bed plants—slight watering daily and a drenching once a week. A lady consulted me on the care of a favorite large Gardenia Florida which seemed to be dying. I found the roots at the bottom of the box quite dry. She had given it regular but only moderate waterings which, like April showers, wetted merely the upper surface. I had it put into the open ground and it recovered.

The roots of plants follow the course in which their liquid food moves.

In striking a cutting in pots the best place to put it is close to the inner edge of the pot. The pots themselves be it noted are made of baked unglazed clay, and are very porous, so that evaporation through their sides is constantly taking place so long as they contain wet soil. Thus the soluble matter, the food of the plants is drawn from the centre and concentrated near the inner edge of the pot. The roots follow it and come into close contact with the inner side of the pot; other portions of the roots follow the course of the gravitating water, and are found at the bottom of the pot. The nutritious currents radiate, as well as move upwards and downwards.

It has long been known that plants, especially trees, will push their roots toward a supply of manure at some distance. This fact has been thought, even to prove the existence of an instinct or intelligent principle; but it is quite explicable on physical principles. There is the same tendency in water to move horizontally by the force of capillary attraction, as perpendicularly, and even more, for it is not resisted by gravitation. Water being taken up by the roots, the ground between them and the manure heap is rendered comparatively dry. Its place is supplied by other water nearer to the manure heap, holding rich material in solution, until at length this reaches the roots, when they rapidly extend themselves in that direction.

It is not generally of much use to water newly planted trees, except at first to bring the soil into close contact with their roots. Watering plants and trees artificially, deprives them of the nutritious matters in contact with their roots, it being dissolved and drawn away by the surrounding dry soil. Hence some very experienced and judicious gardeners either discard the practice altogether, or use it only to a very limited extent.

It is possible to increase or diminish the depth at which the roots of trees and vines shall be made to grow by planting them at the desired depth, and enriching the soil there; on the other hand by covering the roots with muck or manure, to diminish the alternations of heat and cold, and to protect them from drought, to cause the roots to approach the surface. They will follow manure deeply buried, and are thereby retarded in their spring growth, which may or may not be desirable.*

Trees growing by themselves, push their roots deep, because the ground is exposed to the action of the wind and sun, which warms the soil more deeply, and especially by promoting evaporation, produces active ascending currents, from a greater depth. Below a few feet the upward current is probably rarely taking place, and it is probably languid even at a less depth; little nutriment can be received from stagnant water.

The converse of the most active state of the nutritious current, is absolute stagnation. Below a certain depth, probably a few feet, the condition of the earth as respects chemical change, is nearly stationary, and the movement of water upward is of rare occurrence and slight in degree.

Where there is no decomposition, there is no supply of nutriment. The food of plants must not only be existing in the earth, it must be dissolved and applied to the roots, or vegetation ceases.

Thus we are led to a knowledge of the reason, why surface soil is so much valued; why the farmer turns it under to bring it into contact with the roots of his crops; why it is sought after for plants in pots, and for newly planted trees. We are further led to an explanation of the principles by which the roots of plants regulate their depth in the soil. They seek the surface as the place where their food is most abundant; but within a certain distance they may not come, by reason of excessive cold or heat, or dryness, or the presence of light. In dense forests, the roots of trees in general, are very near the surface, being there protected from the sun, and also from the sudden heat following frost, which more than continued cold, is so injurious to vegetation. Hence forest trees are very apt to be blown down if left alone.

*Dr. Underhill, whose success in raising native grapes, at Croton Point in the Hudson river, is so well known, buries his manure (street manure generally) very deep. Thus the full stimulus of heat does not reach their roots until late in the season; thus the energies of the vine are not directed to the making of wood but of fruit. The first pushing of the vine is independent of the roots.

Stagnant water is known to be injurious to all, and fatal to the larger number of plants; let us inquire into the reason of this well known fact. When water, especially that which is known as light water, is placed in a glass vessel where we can see what is going on, we may observe numerous small bubbles adhering to its sides; these consist of common air, but with a double proportion of oxygen. Long boiled water makes bad tea, because all the air is expelled; freezing also expels the air.

If in a vessel containing a little water, some lively beer is poured, the frothing is checked; the water absorbing the fixed air or carbonic acid. This shows how readily these substances combine. I filled a decanter with Croton water, in which a well rooted hyacinth had been living for two weeks or more. I then placed the decanter in a vessel of tepid water, and made it boiling hot. The proportion of air bubbles was very small when compared with that from Croton water recently drawn from the same hydrant, and treated in the same way; its food had been extracted. Bulbous roots will flower in water, but will not go to seed; the seed contains mineral elements which water does not supply.

In swampy forests the roots of the trees are partly above the surface of the ground; evidently they are avoiding the stagnant water as much as possible, and drawing their food from little elevated ridges, where the earth is partly dried. Deep planting of trees is known to be injurious; even a willow tree, as happened to myself, carefully removed only a few rods, but planted a foot deeper, died. I know an orchard on Long Island which has languished thirty years, having been planted too deep. Growing trees are killed if their roots are covered with a very moderate thickness of soil spread over them; in these cases trees are not strangled for the want of air, but they suffer or die from the want of the necessary alternations of temperature, and from the languid movements of the nutritious current, and the arrest of the process of decomposition arising from the exclusion of air; for trees will thrive though air is excluded from their roots, if nutritious fluids are supplied, as in cities under flag stones.

The value of land, so far as it is determinable by chemical analysis, depends not on the amount of valuable materials in a given weight of soil, but inversely on the surface or area from which such soil was taken. *Bulk* is also an element of value no less than weight ; more so, indeed, for with a given bulk, the less the weight, the better the soil, so far as fertility is concerned. Roots require room. They may find it by going deep as well as by extending themselves horizontally. But beyond a certain depth, soil is of no value. The leaves and trunks of plants require air and solar rays.

This leads me to make some observations on *Tillage*. Earth thoroughly tilled, by plowing, harrowing or digging, occupies from one-fourth to one-sixth more space than when it lies compact. It has been stated that it requires sixty years to regain its original compactness, after it has been loosened. The increase of bulk indicates the amount of air and water it contains. Now, air and water, and heat, are the great agents of decomposition; and by decomposition alone, is food prepared for plants. It follows, therefore, that the perfection of tillage, is to afford, with a due degree of heat, the greatest amount of air and water.

The rapidity and extent to which diurnal changes of temperature take place in valleys, is attended with a corresponding degree of respiration of the soil. Hence one reason of their fertility—their greater *dewiness* is probably another; still, it must not be forgotten that they usually contain fertilizing matters washed down from high lands.

Water is useful not only as an agent of decomposition, but also for the food it contains, derived originally from the sea and from the earth. In the city of New-York, the rain water is highly charged with smoke and soot, and common salt. The effect of this latter material, so useful to many plants, is seen on the tin roofs. They are corroded by it below the highlands: above the highlands, they remain bright without painting.

The sources of water in the soil are these:

1. That which comes from below, and which is always injurious;
2. That which falls in the form of rain, snow, hail, &c.;
3. That which collects from precipitation, as dew;
4. That which is attracted to the soil from the atmosphere. The property of so attracting moisture, is much increased by organic manure, which thus becomes a means of rendering the mineral food available.

The necessity of air for decomposition, is seen in the effect of paint and varnishes, which preserve wood by excluding air, and also in the mode of preserving meats and fruits and grain in air-tight vessels. Seeds will not germinate without the presence of air, and may be kept good for an indefinite time.

Soil is rendered warmer when by tillage it ceases to be saturated with water, to the exclusion of air. The effect of heat in producing decomposition is too well known to require illustration. The dead carcass of the mammoth, with the hair and flesh on it, was found not many years since in Russia, covered with snow. Battalions of the

French army, after the retreat from Moscow, are said to have been found even standing; frozen corpses, revealed by the thaw of summer.

Whether the sun's rays are capable of promoting decomposition in the soil, independently of their heat, is yet not altogether decided. But reasoning from analogy, it is probable that they are: for there is a chemical ray, beside the ray of heat and that of light, and probably yet another, which Prof. Draper and others have called the Typhonic ray, or ray of *dark light.*

The moon's rays, which are light without heat, are popularly believed to promote the decomposition of fish and of meat. This may be only that these substances condense dew on moonlight nights. The sudden withdrawal of the sun's rays, rapidly cools the leaves of plants. In proportion as they are rapidly cooled is dew collected upon them, and this precipitation retards the cooling process. Again, in the morning, the evaporation of the dew prevents the leaves from being too rapidly heated. Hence judicious gardeners never meddle with plants until the dew is dryed off. I have seen the leaves of young clover killed by walking upon it so as to shake off the dew just before the sun's hot rays fell upon them. So the gardener, whose tender plants have been frozen, wets them, and protects them from the sun, and so the surgeon puts a frozen limb into cold water.

In the tillage of soil, the aim of the farmer should be to give it the largest possible capacity for respiration and for food, i. e., for air and moving water, the preparers and the carriers of the food of plants.

Of subsoiling and of deep plowing.

If in an exhausted soil appropriate mineral elements exist in a compact subsoil at a depth not too great for the roots of a given crop to reach it without getting into a region of too low a temperature, or of water at rest, subsoil ploughing will be found useful. It may on the other hand prove injurious, if it invite the roots below the region of the required warmth in summer or the required cold in winter; for cold is necessary to the repose of perennial plants. Gardeners cut off the tap roots of some kinds of trees, and place slate under some plants to keep their roots near the surface. The roots of trees may be invited to the surface by top-dressing, and they feel the influence of the sun earlier in the season; but a severe winter following, they may be injured.

If the subsoil is already permeable to water, a further loosening of it may permit the water to pass down too easily. In the alluvial gravelly subsoil of Long Island, subsoiling has proved injurious.

The utility of subsoiling, appropriately used, is three-fold: It is a protection against drought; it gives more space for plants in a given area to find their food; it brings appropriate mineral food within their reach. Deep plowing brings mineral elements to the surface and increases the depth to which the roots may go. The utility of it depends upon the habit of the crop, and in general upon the quantity of manure it is intended to supply, or of vegetable matter already existing in the soil. If a very heavy manuring is intended, a proportionate quantity of new earth may be raised to the surface. It may happen that the first effect is bad, but the ultimate effect is beneficial. If the subsoil is brought to the surface in the autumn, the winter will improve it, for freezing is a very effectual mode of pulverizing the earth.

The rationale of all these processes is this: The three great agents of decomposition, air, water and heat, are set in action to afford food for plants, and the loosened soil permits the roots to extend themselves.

In plowing between crops already in the ground, the surface of the soil, its richest portion, is turned under, so as to be placed in contact with them. By cutting some portion of the roots, as in the case of Indian corn and of potatoes, I have imagined that, like the branches of trees, they might be strenghthened by pruning, and that a temporary check to the growth of the straw was favorable, under some circumstances, to the formation of the grain and the tubers; upon the same principle as that by which we hasten the bearing of fruit on trees, by cutting their roots or bending down their branches.

How a wet soil is also a cold soil, may be thus explained: If the water come from below, it has the temperature of spring water, which is about the medium temperature of the whole year, and of course much colder than that of summer, when vegetation is in progress. Moreover, soil saturated with water has a greater capacity for heat, and consequently requires a longer time to become heated than earth merely moist. But there is still another reason: If a tight vessel be placed in the open air, so as to receive all the rain water that falls, it will be found dry during a great part of the year; the evaporation going on faster than the supply of water. Now it is known that all the water which falls upon the earth does not evaporate. If 30 inches of rain fall in one year, probably as much as one-third descends into the depths of the earth. The necessary conclusion is, that water is not evaporated from the earth, so fast as it is from the surface of water. Indeed the greater dampness of localities near a large surface of water, and especially of insular situations, places this conclusion beyond all dispute. But evaporation is a very cooling process—Hence it is that earth is warm, other things being equal in proportion to its dryness. The efficacy of draining is, that it permits the earth to become warmed, gives motion to the water in it and allows it a due measure of respiration after suitable tillage. In soil partly dry the dissolved food is in a state of concentration, especially near the surface. Plants in a soil ever wet, like children fed on slops, never thrive.

In all these matters, theory and practice are in perfect accordance.

I have thus endeavored to express in a brief and popular, and I hope intelligible manner, some of the most important truths of agricultural science; and I have ventured to add some original reflections, which have not yet received the sanction of the scientific public. The attention with which you have been pleased to listen, assures me that I have not been altogether unsuccessful in this humble effort to connect sound theory with successsful practice.

Mr. President and Gentlemen :

Shall I be pardoned if in this presence I obtrude a single remark on a different subject ? The agriculturist and the man of science, are not fairly dealt with. The literary man has his copy-right for his brain labor, the mechanic has his patent for his invention; but the farmer, who seeks to improve his art, and the man of science, have no protection whatsoever. The value of a single patent-right, exceeds the whole outlay of the State for the improvement of agriculture and the promotion of science. Who pays for the patent? indirectly the farmers pay almost all. Is not this class legislation? But I cannot trust myself or presume to detain you longer. Your Comptroller's accounts are not unlike Fallstaff's bill: Sack, 5s. 8d.; Bread, ½d.

Mr. President and Gentlemen :

I have detained you long and must thank you for patient attention.

In the arrangement of Providence, how little comparatively has been left for man to do in drawing from the soil the means of his subsistence—not more than enough to develop the energies of his mind and body. A self-producing soil, a soil demanding no labor, is fit only for barbarians and slaves. Mental and physical labor is the only condition of existence compatible with intelligence and freedom. Wild animals and a virgin soil are provided for the pioneers in new countries. After a time, civilized man must rely on regular agricultural labor. The greatest development of his moral and intellectual faculties,—the highest perfection of his nature, result directly or indirectly from such occupation.

Mr. President and Gentlemen :

We have seen that in all the changes which matter undergoes, the loss of a single atom is carefully guarded against. Who can doubt that the finer part of himself—his spirit, too, will be preserved, and like the seed you plant, rise to a new state of existence; and in view of the benevolent arrangements for man's happiness here, that each one has it in his power to secure happiness there with Him who alone knows no change.