# LECTURES

ON

# AGRICULTURAL CHEMISTRY,

OR

## ELEMENTS OF THE SCIENCE

OF

## Agriculture.

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# PREFACE

## To the Second Edition.

The first edition of the following Lectures was submitted to the Public at the close of last year. The favourable reception awarded by Agricultural Societies* and other public bodies, to an attempt at a familiar exposition of the principles of farming practice in their application to the circumstances of this country, has induced me to prepare the present volume with increased regard to the purposes I design it to fulfil. I do not pretend to offer anything new in the Science or Practice of farming. I have merely endeavoured to draw a popular illustration of the relations which exist between Vegetables and the mediums in which they grow, on the one hand, and between

* I have much satisfaction in being able to state that the authorities of the Societies &c., whose names are subjoined, have distributed copies of the 1st. Edition of these Lectures among their members and otherwise :—

| | No. of Copies. |
|---|---|
| Provincial Agricultural Association, | 100 |
| County of Kent Agricultural Society, | 114 |
| County of Oxford do. do. | 80 |
| Council of Public Instruction | 60 |
| Teachers Institute-per Geo. Alexander Esq. of Woodstock, | 25 |

vegetables and animals on the other; deducing from the knowledge we possess of their relationship, the proper course to be pursued in attaining the most favourable development of cultivated plants, and of domesticated animals. In describing the rationale of those artifices which are suggested by experience and acknowledged by Scientific and Practical men to be inseparable from a judicious farming practice, I have had especial regard to the circumstances under which husbandry is prosecuted in Canada, in relation to Climate, Markets, and tenure of Soil, as well as to that *mixed system* which universally prevails in this Country. It would have been a useless expenditure of time and materials to have described the details of many artifices which especially belong to what is called "high farming;" artifices which are not susceptible of adoption in Canada at present.

It has seemed to me that the chief objects which should arrest the attention of Canadian farmers, are to preserve the naturally fertile Soils of the country from DETERIORATION, and to restore the fertility of such as have been already impaired.

The principles and practice involved in the artifices which secure those objects, are the same which, when pushed to excess, constitute high farming—a system of practice which may succeed well in countries or localities where land lets for fifteen dollars an acre per annum, but which is commercially impossible in this Western Province, where all farmers are proprietors, where excellent land is abundant and cheap, capital scarce and dear, wages immoderately high, and the price of produce variable and low.

I have addressed myself to the practical farmer and student, in language as free from the technicalities of Science as possible, under the conviction that the real bone and sinew of the country, have for their elements men who handle the plough and wield the axe with untiring energy, and are yet unwilling to let the understanding lie fallow or unproductive, when reasonable opportunity of exercising and improving it is offered to them.

The division of the Lectures into sections, will probably afford common-school teachers some assistance in presenting the extensive subject of Agricultural Science to their pupils in the form of short teaching Lectures, for each of which, one of the sections of the recapitulation is designed to serve as the subject.

# CONTENTS.

## Part First.

### ON THE RELATION OF VEGETABLES TO THE AIR AND SOIL IN WHICH THEY GROW.

### LECTURE I.



### LECTURE II.



### LECTURE III.



### LECTURE IV.

# Part Second.

## ON THE RELATION OF VEGETABLES TO ANIMALS.

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### LECTURE V.



---

### LECTURE VI.



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### LECTURE VII.



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### LECTURE VIII.

# ELEMENTS

OF THE

# SCIENCE OF AGRICULTURE.

## Part First.

## ON THE RELATION OF VEGETABLES TO THE AIR AND SOIL IN WHICH THEY GROW.

### LECTURE I.

Introduction — Object of Agricultural Chemistry—Matter—Simple Bodies—Conditions of Vegetable Life—The Atmosphere — Its Composition and Properties—Atmospheric Food of Vegetables—Carbonic Acid — Influence of Light—Water—Its Relations to Solids and Gases—Its Composition—Ammonia—Nitrogen —Organic and Inorganic Elements of Plants—Composition of Vegetables—Recapitulation.

1. We rarely appreciate the value of any science in its state of infancy. It is generally impossible to forsee what useful results may flow from its practical application. When, however, it leads to a discovery or invention, which may be brought to bear with advantage upon industrial labour, it soon acquires a popular interest, which ensures its rapid spread. The science of Electricity created no stir in the arena of practical life, until electro-

plating and the telegraph gave it importance in the eyes of practical men; and now we know what it has done, our anticipations are almost boundless of what it may yet be made to do; many of us looking forward with confidence to a day, probably not far distant, when additional discoveries will enables us to convert it into a source of cheap and commodious motive power.

2. The science of Chemistry has for ages been the handmaid of the manufacturer in the preparation of raw materials for useful and refined purposes. It is only of late years that her aid has been sought by the producer, but with such successful results, that the light which the application of Chemistry to Agriculture has thrown upon his operations, enables him to convert an experimental art into an intellectual and noble science. A branch of knowledge, hardly a dozen years old in its practical application, can, however, scarcely be supposed to have met with an extended appreciation among the farming communities of Canada, or even to have attracted the special attention of Agricultural Societies or private individuals, whose means and opportunities would appear to afford them better facilities for improving their acquaintance with it.

3. It has been most fully established, that Husbandry, in all its branches, affords a wide and interesting field for intelligent observation. The most insignificant operation of practical Agriculture, indeed, presents material for patient reflection and minute enquiry. The farmer may engage in a routine of manual labour, established by experience, and requiring the mere exertion of muscle, with results satisfactory to himself; he may also asssociate

with bodily exertion, the higher exercise of his mental gifts, promising him greater remuneration for his industry, and a better acknowledgment of his privileges as an intelligent member of society.

4. In its first stage of development, the relation of Chemistry to Agriculture was necessarily very obscure and often much misunderstood. The most sanguine and exaggerated expectations were entertained respecting the results to which it promised to lead while in this obscure condition. The non-realization of immoderate hopes, paved the way for the substitution of violent prejudices against Scientific Agriculture in the minds of many practical men; neither was it until materials drawn from experiments, confirming or modifying the prognostications of theory, assisted in framing a scientific system of Agriculture, that the visionary anticipations of multitudes became sobered down into a proper apprehension of the actual good to be obtained by its adoption; an event which has taken place during the last six or seven years. What Chemistry has already done for Agriculture is immense: what she may yet do is incalculable. And now that a clear insight into their relationship is established, the difficulty of presenting a popular view of the subject has almost vanished.

5. Very strong prejudices still exist among practical farmers against book-farming, prejudices which have not unfrequently arisen from disappointed hopes, and even ruinous loss in following arbitrary rules, without understanding the principles upon which they are based. Agricultural Science, adapted to the practice of every-day life, is no system of book-farming; it presents no prescribed

rules to be implicitly obeyed. It portrays in simple language, devoid of technicalities, the *reasons* why farmers plough, drain, fallow, and rotate their crops; it shows how repeated cropping, without the application of manure, must inevitably ruin for a time the most fertile soil; and it establishes such an intimate relationship between the soil and the kind of vegetable growing upon it, that every farmer may frame for himself a rational system of Husbandry, as varied as the soil he may chance to cultivate.

6. It has been occasionally urged, by some persons who profess to speak from experience, probably acquired in a very contracted sphere, that Canadian farmers, in possession of a fertile soil, do not at present require the aid of a systematic system of agriculture. Such an objection, rarely advanced it is true, may be dismissed by a reference to the present deteriorated condition of many fertile regions, and to that growing desire which every intelligent and enterprising farmer exhibits, to make himself acquainted with the rationale of agricultural processes, as well as to the invariable success attending the acquirement of such information when judiciously applied.

7. The complaint of diminishing scales of produce, is general throughout the older settled portions of the United Provinces; it has been long and loudly urged in New England and in the State of New York. History, moreover, furnishes us with numberless examples of once famed fertile soils, in all quarters of the world, now scarcely able to make a quadruple return.

Professor Norton, says, that "in many of the Eastern States, where wheat was once largely grown, its culture has greatly decreased; and in some districts scarcely any is to be found, excepting an occasional small patch of spring wheat. It is common to ascribe this to the Hessian fly, to the prevalence of rust, &c.; but after we have made all due allowance for these causes of uncertain produce, the principal reason, in my judgment, is to be found in the deterioration of the land."

"The state of Agriculture in the northern part of America, in our own provinces, and in New England, is generally what the state of agriculture in Scotland probably was 80 or 90 years ago. In some parts of New Brunswick they are very nearly in the precise condition in which Scotland was 120 years ago. Go as far west as you like, and as far south as you like, the same general description applies to the whole."—Professor Johnston.

8. Enquiries into the causes of these results inform us, that they are the natural consequences of the system of farming pursued. Where little attention is paid to a judicious rotation of crops, to surface draining, to the proper preservation of manures, or to the mode of applying them, to the destruction of weeds and the selection of seed,—in a word, to as careful a management as circumstances will permit of all farming operations,—can we be surprised that the average of Canada's staple product, wheat, is *less than one-half* the average of England and many parts of continental Europe.

9. Another objection to the general adoption of Scientific Farming practice, is said to be found in the circumstances by which Canadian farmers are frequently surrounded—distance from markets, the high price of labour, the low price of produce and of land, all conducing to foster a system of Husbandry directly opposed to rational views.

In answer to this objection, we may urge, that Agricultural Science is replete with suggestions, many of which may be received, and many, if not found remunerative, rejected; it moulds itself to every condition of locality and circumstance, and wherever calculation proves that some of its suggestions are not remunerative, they can form no part of a rational system for that neighbourhood.

10. The local experience of every farmer in the country, will afford him abundant illustration of the vast difference in the results produced by good and bad farming. There is not an old settled Township in the Province, which does not furnish many instances of intelligent and well-informed men, annually reaping double, and sometimes treble the average amount of produce from their farms, their neighbours are vainly endeavouring to obtain. When we consider the circumstances under which successful Agriculturists, with no pretensions to scientific knowledge, have arrived at that course of operations which ensures to them favourable results, we cannot fail to discover, that experience extended over many years, and perhaps generations, has given them the clue to success. But, when the scene of operations is changed, when the farmer has to grapple with a NEW SOIL and a NEW CLIMATE, or when the valuable results of EXPERIENCE are either inapplicable, neglected, or unknown, it is then that Agricultural Chemistry, by descending to elementary principles, DIRECTS the farmer how to build up a system of Husbandry, adapted to every kind of soil and every variety of climate, in which cultivated crops are capable of being produced with advantage. The chief design, therefore, of Agricultural Chemistry, is to investigate—

1st. The relations of Vegetables to the Air and Soil in which they grow.

2nd. The relations of Vegetables to Animals.

11. Since there is not the slightest ground for the supposition that vegetables or animals create matter, every portion of their structure being derived either from the air or the soil, it is manifestly of importance to know the nature of those substances which serve the purposes of food. We can only obtain this information by endeavouring to ascertain what simple substances are common to air, soils, vegetables, and animals, and to trace, as far as the present state of the science enables us, in what way this mutual interchange takes place. It is almost needless to remark, that we must not expect to find any simple substance in a vegetable or in an animal which does not exist in one form or another in the air or in the soil.

12. The solid substances which compose the earth, together with most of its numerous and diversified inhabitants, have been carefully examined by chemists, and the materials of which they are composed subjected to minute and exact comparison. This examination has terminated in the singular result, that, notwithstanding the infinitely varied mineral, vegetable, and animal forms which present themselves to our observation, ALL are composed of one or more of sixty different simple indestructible substances; that is to say, of substances from which nothing different from themselves can be obtained by any known process. All the metals furnish us with illustrations of simple or uncompounded substances—water, wood, flesh, and, indeed, every part of vegetables or animals is formed by the union of two or more simple substances. Many

varieties of these bodies are rarely to be met with ; some of them never occur naturally in a simple state, being always compounded with other bodies, and only capable of being separated from them by means of intricate artificial processes. Others, again, are constantly present in animals and vegetables—consequently, also in the air or fertile soils. The number of those simple substances which enter into the composition of cultivated plants and domesticated animals is not necessarily greater than FIFTEEN, and in general FOUR out of the fifteen build up nineteen-twentieths of their structure. It thus becomes a matter of interest to enquiring men, and of moment to practical farmers, that they should obtain a familiar acquaintance with the powers, properties and distribution of the fifteen simple bodies which play such an important part in the marvellous processes of vegetable and animal life.

13. A very superficial examination of the circumstances under which vegetables grow, furnishes us with the conditions upon which their life and health are dependent. They are six in number :—

1. The Composition of the Air.
2. The Composition and Mechanical Properties of the Soil.
3. The Moisture of the Soil.
4. The Moisture of the Air.
5. The Temperature of Air and Soil.
6. The Presence of Solar Light.

The second condition, namely, the Composition and Mechanical Properties of the Soil, is the only one of the six over which the farmer can exercise any direct control.

The composition, however, of air is invariable, the presence of solar light nearly so; and the effects of too much or too little moisture, in the form of rain or vapour of water, as well as of too high or too low temperatures, can be wonderfully ameliorated by those artifices which experience and the Science of Agriculture suggest.

THE AIR, OR ATMOSPHERE.

11. Pure country air is composed of two invisible gases, in which a small, yet variable amount of vapour of water is always dissolved, together with a minute quantity of a sour-tasted gas, called Carbonic Acid, or choke damp. One hundred ounces of air contain about—

76 ounces of a gas called Nitrogen;
23 ounces of a gas called Oxygen;
1 to $1\frac{1}{2}$ ounces of Vapour of Water;
$\frac{1}{20}$ of an ounce of a gas called Carbonic Acid.

These gases are intimately *mixed* together, and always in the same, or very nearly the same proportions; this uniformity of composition obtains at all altitudes, whether air is taken at the level of the sea or from the tops of high mountains.

Nitrogen is a kind of simple air or gas; it is tasteless, invisible, extinguishes flame, and is destructive to animal and vegetable life in its pure state. It serves to temper and weaken the powerful effect of Oxygen, with which it is mixed in the air we breathe. It may be procured sufficiently pure for ordinary experiments by the subjoined process:—Place a short candle in a basin, pour some lime water (see art. 167) round about the candle, until it rises within an inch of the wick. Take an empty bottle with a wide mouth, light the candle, and carefully put the inverted bottle over it, until it dips half an inch below the surface of the water. In a few seconds the candle will go out, having, during the process of combustion, consumed all the Oxygen and produced Carbonic Acid, (art. 19.) The water will rise in the bottle when it cools. Cork under water, and shake the bottle. The Carbonic Acid produced by the combustion of the candle, will combine with dissolved lime, and render the water milk-white. Nitrogen, nearly pure, remains in the form of an invisible gas.

Oxygen is a simple gas, possessing many extraordinary properties. It is destitute of smell, colour, and taste; all bodies burn with increased energy in Oxygen, and animals, when they breathe in its pure form, are thrown into a state of the greatest fever and excitement, which soon terminates in death. It forms Oxides or Rusts when it combines with Metals, as for instance, with iron, which, when exposed to air, unites with the component Oxygen, and forms Oxide or Rust of Iron. It is also a great acidifying agent, forming powerful acids when it combines with certain bodies, as with Sulphur, to form Sulphuric Acid or Oil of Vitriol; with Nitrogen, to form Nitric Acid, or Aquafortis. Oxygen is very generally diffused; it constitutes eight-ninths of water by weight, and is found to form a large portion of rocks, stones, soils, vegetables, and animals. Its presence in the pure state may be shown in the following manner:—

Fill a glass with water, invert it, and let it rest upon a saucer filled with the same fluid. Place some green leaves under the glass and expose them to the direct light of the sun; bubbles of gas will soon be seen to form upon the surfaces of the leaves. The gas is pure Oxygen. It is obtained from the decomposition of Carbonic Acid by the leaves, under the influence of the sun's rays. The bubbles will cease to be formed when all the Carbonic Acid contained in the leaves and water is decomposed. Put some bits of chalk or limestone and a few drops of vinegar into the water; the operation will be renewed; Carbonic Acid being liberated from the chalk or limestone.

15. The Air or Atmosphere extends to the height of about 15 miles, and presses upon the surface of the earth with a weight equal to 15 lbs. on every square inch of surface, or equivalent to that which would be produced by a sheet of iron five feet in thickness; it is nevertheless, 814 times lighter than water, one cubic foot weighing 535 grains. During thunder storms the passage of lightning through air, causes the formation of a substance named Ammonia,—(art 31.)—a gas of very pungent odour, readily absorbed by water, and familiarly known by the name of Spirit of Hartshorn. Rain water invariably contains Ammonia, which it collects from air in its descent to the earth.

16. Air, upon which the life of all vegetables is dependent, contains, as we have seen, apparently insignificant quantities of three bodies, Carbonic Acid, Water and Ammonia. One of the most astonishing results of the application of chemistry to vegetable life and organization, is embraced in the discoveries, that,

1st. Nineteen-twentieths by weight, of all vegetables, are derived originally from the air we breathe;

2nd. The atmospheric or air food of vegetables exists in the forms of carbonic acid, water and ammonia.

17. These important principles in Agricultural Chemistry may be made more evident, by the following illustration: Let us suppose we burn completely 1000 lbs. weight of hard wood in a stove or fire-place, and carefully weigh the ashes which remain behind. They will be found to constitute about one-twentieth of the whole mass of the wood, weighing not more than from 30 to 50 lbs., according to the kind of wood burnt. The whole of that portion which goes off in the form of smoke, vapour of water and gases, existed at one period in the air we breathe, in the forms of Carbonic acid, Water and Ammonia. The whole of the ashes were obtained from the soil in which the trees originally grew.

18. We may now proceed to consider the properties and sources of the atmospheric food of vegetables, and endeavour to ascertain the manner in which it assists in building up their structure, also to what extent the formation of their different parts or organs, is dependent upon a proper supply of each particular kind of food.

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## ATMOSPHERIC, OR ORGANIC FOOD OF VEGETABLES.

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19. Carbonic Acid.—This important gas food of vegetables possesses many singular properties. It is poisonous to animals, incapable of supporting combustion, inodorous, sour-tasted, and considerably heavier than the air we breathe. It is composed of Carbon or Charcoal and Oxygen; in twenty-two pounds weight of this acid gas, there are six pounds of Carbon and sixteen pounds of Oxygen. Water absorbs it with avidity, and thus acquires the power of dissolving chalk and limestone. Carbonic Acid is an

active agent in loosening and separating into their constituent parts the surfaces of solid rocks, stones, and soils. It possesses the power of forming combinations with certain substances found in rocks, such as potash, soda, &c. Some of the compounds thus formed, being soluble in water, are washed out of the rocks by rains and dews, leaving the surface to a small depth extremely porous, and capable of being disintegrated after the manner shown in art. 26.

*The leaves of plants absorb Carbonic Acid from the air which envelopes them, during the day time ;* it also enters into the plant along with the water absorbed by the roots —Carbonic Acid being always present in fertile soils. (art. 74.)

**20.** When direct or diffused light from the sun falls upon the green parts of vegetables, they acquire the power of decomposing Carbonic Acid—that is to say, of separating the Carbon from the Oxygen. The Carbon enters into the substance of the vegetable, and thus assists in building up its structure, and is said to be assimilated. The Oxygen is given off by the leaves of land-plants, and by the roots of water-plants in the form of a simple gas.

During the night time, the Carbonic Acid contained in the water drawn up by the roots, is given off by the leaves unchanged—few plants having any power to separate the Carbon from the Oxygen during the darkness of night. The inability of cultivated vegetables to form green colouring matter in the absence of light, may be shown by shading a leaf, or an entire plant with a common flower-pot: it will become pale-coloured or white. In the absence of light, the leaves cannot decompose the

Carbonic Acid they absorb. The brilliant colours of different kinds of roses are produced by a constitutional inability to decompose Carbonic Acid. If the petals of the flowers decomposed as much as the leaves, they would be green. When potatoes are exposed to the light of the sun, the rind absorbs Carbonic Acid—decomposes it, and forms green colouring matter.

21. Carbon, when pure, exists only in the solid form: it then constitutes the diamond. Lampblack and Charcoal are impure forms of Carbon. Carbon is insoluble in water; it must necessarily combine with some body in order to assume the gaseous state, or become soluble in water, before it can serve as food for vegetables. We thus find it in the form of Carbonic Acid, which is not only gaseous, but also very soluble in water: two characteristics, which ensure it a double access into the system of vegetables, either by the leaves in the form of a gas, or by the roots when dissolved in water. The leaves of forest trees will absorb all the Carbonic Acid from the air which passes through them, during the continuance of a gentle breeze, in bright sun-shine.

22. A popular opinion prevails that some plants possess the power of turning their leaves to the sun. The motion observed is purely mechanical, and depends upon the rapid liberation of Carbon from the absorbed Carbonic Acid in those parts of the plant which are exposed to the direct rays of the sun. The liberated Carbon stiffens and contracts one side of the plant in forming new wood, while the other remains comparatively flexible. The contracted side becomes arched, and appears to give to the vegetable a limited power of motion in the direction

of light: a brilliant artificial illumination produces the the same effect in the ratio of its intensity. When Carbon is separated from Carbonic Acid, it combines with the component parts of water, and forms woody fibre, starch, gum, sugar, and oils. Carbon obtained from Carbonic Acid, forms from 15 to 50 lbs. in every 100 lbs. of the *dry* wood, stalks, and seeds of cultivated plants.

23. Carbonic Acid is the immediate source of all the Carbon or Charcoal in vegetables; and with the single exception of Ammonia, Carbon exists in all substances of exclusively vegetable and animal origin. The constant presence of Carbonic Acid in the air we breathe, is due to the respiration of animals, (art. 166 and 167,) the combustion of bodies, and the decay of vegetable matter. If all the Carbonic Acid present in the atmosphere were collected in one spot, in its gaseous state, it would occupy a space of more than 180,000 cubic miles. A vast store exists in the extensive limestone rocks which form a large portion of the earth's crust. Pure limestone, indeed, is composed of one-half Lime and one-half Carbonic Acid, which may be driven off in the gaseous form by means of a violent heat, as in the operations of limekilns. This acid gas may be obtained in the following manner:—Pour strong vinegar upon some pieces of chalk or limestone; violent effervescence will be observed, caused by the liberation of Carbonic Acid from its union with the lime of the chalk, or limestone. If the chalk is at the bottom of a deep glass vessel, heavy Carbonic Acid will displace the air, and a lighted piece of paper being introduced, will be immediately extinguished.

24. WATER.—This abundant and necessary fluid is

known to the agriculturist in five states, the solid, (ice,) the fluid, (water,) the gaseous, (vapour of water, steam,) the vesicular, (clouds, mist,) and in combination with certain bodies, (slacked lime.) When water freezes, that is, assumes the solid state, it expands with astonishing force, sufficient to break the strongest vessels. Many remarkable results are produced by the expansion of water when converted into ice, among which, the floating of ice, is perhaps, the most deserving of notice. If water, in becoming solid, followed the almost universal law of contraction, ice would sink, and yearly increasing in thickness at the bottom of deep seas, lakes and rivers. would produce such a change in climate as probably to convert the greater portion of the temperate zones into desolate and uninhabitable regions.

25. We discover, however, a still more beautiful provision for arresting the conversion of oceans and seas into solid masses of ice, in the singular property of water occupying the least space, and being consequently heaviest, at the temperature of 40 degrees—eight above the freezing point. The warmth of seas, at depths beyond the influence of the sun's heating rays, is thus perfectly uniform, effectually preventing the Arctic Oceans from becoming solid and immovable masses of ice.

The Climate of Western Canada, south of the 44th parallel of north latitude, is influenced to a very great degree by Lakes Ontario, Erie, and Huron, which remain unfrozen all the year round. The mean winter temperature of large tracts of country, situated to the east of the Lakes, is 24°, on the Lakes 27°, and west of the Lakes 20°.

26. During the autumnal months, rain and dews pen-

etrate the minute crevices and pores of solid rocks and clods of earth, (art. 19.); in the winter months the water freezes, and expanding, tears their particles asunder; thus gradually reduces the hardest rocks into a soft and friable soil. To the alternate thawing and freezing of water in the soil during the early spring months, and its consequent contraction and expansion, the "throwing out" of young wheat plants is to be attributed, a disaster which may be materially prevented by draining.

27. When water is converted into steam, or slowly assumes the form of vapour, during the process of evaporation, it absorbs a vast quantity of heat, (art. 160.) Under ordinary circumstances, one cubic foot of water will occupy 1700 cubic feet of space when converted into steam; but when it is transformed into vapour by evaporation, at ordinary low temperatures, and mingles with the air, it expands 80,000 times. The quantity of water capable of being suspended in air, is dependent upon the temperature. When air is perfectly saturated with moisture, the least diminution in temperature compels a portion of the suspended vapour of water to assume the vesicular state, as cloud or mist. When the reduction of temperature takes place on the surfaces of bodies, the vapour is deposited in the form of dew. It is thus, that after the sun has set, the leaves of vegetables on cloudless nights rapidly becoming cool, by the radiation of their heat into the clear expanse above them, chill the surrounding air, and cause it to deposit upon their upper surfaces the moisture, which, in its chilled state, it cannot retain.

The quantity of this revivifying agent condensed on the leaves of vegetables in the Canadian Peninsula is very great, and furnishes one important reason why Western Canada is less liable to suffer from those destructive droughts which are common to the West of the Lakes, and not unfrequent towards the East and South.

We may safely infer, that under our comparatively serene summer sky, in connection with a humid atmosphere, the annual deposition of dew on forest lands amounts to about 600 tons per acre, which, dripping from the trees, and being sheltered from solar radiation by the dense shade they produce, furnishes a steady supply to swamps and shallow springs.

28. Most solids and gases are soluble in water; the very existence of vegetables and animals is dependent upon this property. It is thus that river and well water contain small quantities of lime, potash, soda, magnesia, iron, besides air and Carbonic acid. The refreshing and agreeable taste of springs is due to the presence of dissolved air; hence, also, recently boiled water is insipid and disagreeable. It appears from recent investigations made under the auspices of the London General Board of Health, that both public and private economy and health, are materially affected by the character of the water employed for domestic and other purposes.

When vegetable or animal matter becomes decomposed, one of the results of decomposition is Ammonia, which, in assuming its gaseous state, *always carries with it* vegetable or animal matters in a high state of putrescency. Ammonia is rapidly absorbed by water, and with it the animal or vegetable substances with which it is loaded. Hence, water kept in open cisterns, or tubs, or even open wells, in the neighbourhood of dung-heaps, stables, or in filthy yards, is sure to be vitiated by putrescent animal or vegetable impurities. If water thus impregnated be boiled, it loses the injurious influences due to decaying matter which may be present. Ordinary filtration will not destroy all the organic impurities of water which has been kept in vitiated or foul air; a good filter of animal charcoal or clay will greatly lessen the quantity.

The use of hard water for cooking and culinary purposes, is open to many objections. In making tea with hard water, containing sixteen grains of lime to the gallon, (a gallon of water contains 70,000 grains,) as much of the leaf is required to make three cups as might make five cups of equal strength were soft water employed. The extra expenditure of tea, when made with hard water, is about one-third. It also appears that soft water evaporates one-third faster than hard water, an important consideration where steam power is required. A single grain of lime contained in a gallon of water destroys a quarter of an ounce of soap; so that in water of ordinary hardness, say eight grains of lime to the gallon, two ounces of soap are wasted in neutralizing the lime. To persons who are accustomed to wash in rain water, river water containing five grains of lime to the gallon would appear hard, and require one ounce and a quarter of soap to neutralize it; that is, to render it soft. Soft water is much more favourable to health, as an article of drink, than hard water. During the late cholera, the inhabitants of a portion of Glasgow enjoyed a singular immunity from the epidemic. The unanimous opinion of the Medical Society was, that this comparative immunity was to be attributed to the soft water supply. Different animals show an instinctive love for soft water. Hard water produces a rough and staring coat on horses, and renders them liable to gripes.

29. Water is composed of two gases: Oxygen, before described, and Hydrogen, a very light and inflammable gaseous body, elementary, invisible, inodorous; and, when pure, destructive both to animals and vegetables. It may be easily procured from water in the following manner:—Introduce some iron turnings or bits of zinc into a small bottle. Make a hole through the cork, and insert the stem of a tobacco pipe, so that it fits accurately. Mix some oil of vitriol (sulphuric acid) and water; about one part of the former to four of the latter. Pour the mixture on the metal, cork the bottle tight with the prepared cork, and after the lapse of a minute apply a light to the extremity of the pipe. The gas issuing from it will take fire. It is Hydrogen, and is obtained by the decomposition of the water. Take a *small* dry phial and collect some of the gas by holding it over the pipe; bring it immediately to the flame of a candle; an explosion will take place, and water be formed, the phial becoming dim with moisture.

If we mix 1 pound of Hydrogen with 8 pounds of Oxygen, and pass an electric spark through the mixture, a union will take place, and 9 pounds of water be formed. Chemists are acquainted with various ways of converting water into its component gases. The perfectly clean surface of many metals, such as iron, zinc, copper, &c., will immediately take Oxygen from water, and liberate a corresponding quantity of Hydrogen, which at once assumes the gaseous state. The water is then said to be decomposed, and the action observed is due to the comparatively greater attraction of the metal for Oxygen than of Oxygen for Hydrogen. The Oxygen, separated from its union with the Hydrogen, combines with the metal, and forms an Oxide or Rust. PLANTS POSSESS THE POWER OF DECOMPOSING WATER, AND MAKE USE OF ITS COMPONENTS, OXYGEN AND HYDROGEN, TO BUILD UP THEIR STRUCTURE.

30. Water is not the only source of Oxygen to vegetables; the leaves of plants absorb that gas from the air by which they are surrounded *during the night time.* It has been found by experiment that the leaves of the spruce-fir, if kept in the dark for twenty-four hours, will absorb ten times their volume of Oxygen. This absorption of Oxygen is intimately connected with the formation of peculiar substances in the leaves and bark, such as resins and oils. The leaves of the oak, which contain a substance called *tannin*, absorb fourteen times their volume under the same circumstances, and the balsam poplar twenty-one times as much. It is a very curious fact that cattle will eat certain kinds of vegetables in the morning, which they will not touch at noon, or in the evening. A change takes place in the taste of the vegetable during the twenty-four hours, caused by the absorption of Oxygen from the air during the night time, and the liberation of Hydrogen from water during the day-time, under the influence of light. In the morning, the vegetables are acid, at noon tasteless, and in the evening bitter. The roots of vegetables possess the power of absorbing Oxygen from the air present in the soil, or from rain-water, which contains three per cent. of that important gas in its pure and uncombined state, dissolving

it during its passage to the earth. Hence, roots should never be covered with an impervious soil which refuses access to air or rain-water. Oxygen is also absolutely necessary during the process of germination in seeds.

31. AMMONIA.—Ammonia, in popular language, Spirit of Hartshorn, is formed in the air by the action of lightning. It is composed of Hydrogen and Nitrogen. Three pounds of the former combining with fourteen pounds of the latter to form seventeen pounds of Ammonia. This body possesses a singularly powerful odour, and an eqnally remarkable attraction for water, which dissolves 780 times its volume at the temperature of melting ice. Ammonia is emitted by decaying vegetable and animal matter; it is also found in the perspiration of animals, and is given off by the leaves of many plants, as well as by the flowers of a still greater number.

32. Rain-water always contains Ammonia, washed from the air through which it passes. Its presence in rain-water can be detected by evaporating a considerable quantity of that fluid—say one gallon—to the bulk of a table-spoonful. Upon adding a little lime, and suspending a feather dipped in Spirit of Salt, or good Vinegar, over the evaporating basin, white fumes will be observed, which indicate the presence of Ammonia. In order to discover its presence in solids, the solid should be reduced to powder, and mixed with an equal quantity of lime, then heated by means of a spirit lamp, and the same test applied as given above.

33. Ammonia is absorbed by the roots of plants along with the water in which it is dissolved; it is found in the juices of all vegetables, and its odour can be perceived

whenever lime is added to the juice of the maple, in the process of making maple-sugar. The characteristic smell of close stables, is due to Ammonia proceeding from the decomposing urine. Many solid bodies possess the power of absorbing large quantities of Ammonia — such as partially burnt clay, rust of iron, gypsum, and especially powdered charcoal, decaying wood and vegetable matter: these substances relinquish much of what they have condensed within their pores, to the water with which they may be saturated. Ammonia is *a very important* portion of the food of vegetables. It is the chief source of the Nitrogen in cultivated crops.

31. It has been a disputed point whether vegetables possess the property of absorbing Nitrogen directly from the atmosphere by means of their leaves, or even of making use of that which is contained in its pure and simple state in rain-water, (about two per cent.) It is now thought to be ascertained that some vegetables do possess the power of using pure Nitrogen as food, and that others can only obtain that body by the decomposition of Ammonia. Some kinds of clover derive a large supply of Nitrogen directly from the atmosphere; whereas grain-producing crops (especially wheat) have no power to assimilate Nitrogen from the air by which they are surrounded, or even feed on that which is taken up into their system by means of the water they absorb from the soil. It is thus that grain-producing crops exhaust the soil of Ammonia—the only common form of food containing Nitrogen accessible to them. Hence, manures containing large quantities of substances, which, upon decomposition, can produce Ammonia, are of special advantage to grain-producing crops. (art. 104.)

Nitrogen is absolutely necessary in the formation of the seeds of plants; and the more Nitrogen the seeds contain, the more nutritious they will be as articles of food. The best samples of wheat contain the largest amount of Nitrogen; derived, probably, nearly altogether from Ammonia. Nitrogen is also found in the juices of vegetables, in forms capable of serving the purposes of nutrition, (art. 124); hence certain kinds of green food are more nutritious than when in the dry state, as green oat straw, green clover, green grasses, &c.

35. It has been remarked, that the three bodies, Carbonic Acid, Water, and Ammonia, constitute nine-tenths of the food of vegetables, and are composed of four simple or elementary bodies, thus:—

Carbonic Acid, from Carbon and Oxygen;
Water, " Oxygen and Hydrogen;
Ammonia, " Hydrogen and Nitrogen.

The simple or elementary bodies, Carbon, Oxygen, Hydrogen, and Nitrogen, are called the ORGANIC ELEMENTS of vegetables and animals, because the organs or parts of vegetables and animals which have functions or duties to perform, which possess an *organized structure*, and are the result of vegetable or animal life, (as the bark, the leaf, the cells of the wood, in vegetables; and the skin, the muscles, the hair of animals) are either altogether, or almost altogether, formed from them. Such substances, however, as stones, rocks, soils, which do not possess any organized form or structure, or any parts having certain duties to perform, are termed *inorganic bodies*, and the simple bodies of which THEY are composed, INORGANIC ELEMENTS. In general, the organic elements of vegetables go off in the form of smoke, &c., when a vegetable is burned, and the inorganic portion constitutes the Ash.

**36.** The ratios in which the simple organic elements enter into the composition of vegetables, vary slightly with different species. If the wood of the oak, the beech, the elm, the maple, or the straw and seeds of wheat, barley, oats, &c., be dried in an oven, so as to drive away all moisture, and the remaining portion subjected to analysis, it will be found that these, and indeed all cultivated vegetables, contain in every hundred pounds weight—

| | | |
|---|---|---|
| From 40 to 50 lbs. of | Carbon, | Organic Elements. |
| " 35 to 45 - - | Oxygen, | |
| " 5 to 7 - - | Hydrogen, | |
| " $\frac{1}{10}$ to 3 - - | Nitrogen, | |
| " 2 to 10 - - | Ash, | Including the Inorganic Elements. |

37. A more exact composition of some important vegetables is given in the following table :—

| | Carbon. lbs. | Hyd'gen. lbs. | Oxygen. lbs. | Nitr'gen lbs. | Ash. lbs. | |
|---|---|---|---|---|---|---|
| Wheat . . . . | 46.1 | 5.8 | 43.4 | 2.3 | 2.4 | = 100. |
| Oats, . . . . . | 50.7 | 6.4 | 36.7 | 2.2 | 4.0 | = 100. |
| Wheat Straw . | 48.4 | 5.3 | 38.9 | .4 | 7.0 | = 100. |
| Oat Straw . . | 50.1 | 5.4 | 39.0 | .4 | 5.1 | = 100. |
| Clover hay (red) | 47.4 | 5.0 | 37.8 | 2.1 | 7.7 | = 100. |
| Potato . . . . | 44.0 | 5.8 | 44.7 | 1.5 | 4.0 | = 100. |
| Turnip . . . . | 42.9 | 5.5 | 42.3 | 1.7 | 7.6 | = 100. |
| Yellow Peas . | 46.5 | 6.2 | 40.0 | 4.2 | 3.1 | = 100. |
| Pea Straw . . | 45.8 | 5.0 | 35.6 | 2.3 | 11.3 | = 100. |
| Jerusalem Artichoke . . | 43.3 | 5.8 | 43.3 | 1.6 | 6.0 | = 100. |

In illustration of the above tables, let us take, as an example, Red Clover Hay. We find that 100 lbs., when well dried, are composed of $47\frac{4}{10}$ lbs. of Carbon ; 5 lbs. of Hydrogen ; $37\frac{8}{10}$ lbs. of Oxygen ; $2\frac{1}{10}$ lbs. of Nitrogen ; and $7\frac{7}{10}$ lbs. of Ash. Or, in other words, $92\frac{3}{10}$ lbs. out of 100 lbs. were obtained from the three substances—Carbonic Acid, Water, and Ammonia, and only $7\frac{7}{10}$ lbs., out of 100 lbs., derived from the solid substances of the earth.

38. When vegetables decay, many and very complex changes take place, but all these finally result in those which restore to the air we breathe, and the soil we tread upon, the substances from which they were originally constructed. "All the innumerable products of vitality resume, after death, the *original form* from which they sprung. Thus, the destruction of an existing generation becomes the means for the production of a new one, and death becomes the source of life."—(Liebig.)

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RECAPITULATION.

1. The application of Chemistry to Agriculture enables us to establish the mutual relations which exist between Plants, Animals, Air, and Soil.

2. A knowledge of these relations teaches us the mode in which we may obtain the greatest remuneration for the least expenditure of Capital and Labour. It elevates an Art into a Science, and associates high intellectual acquirements with laborious, yet honourable industry.

3. Vegetable life and health are dependent upon the composition, moisture, and temperature of the Air and Soil, and the presence of Solar Light.

4. The food of vegetables may be divided into two classes :—1st. Organic food, or that which is obtained chiefly from the Atmosphere ; 2nd. Inorganic food, or that which is obtained exclusively from the Soil.

5. The Organic food consists of Carbonic Acid, Water, and Ammonia. From these substances vegetables derive their chief supply of the solid Carbon, and the gases Hydrogen, Oxygen, and Nitrogen, which build up about ninety-five hundredths of their bodies.

6. Carbonic Acid ; a non-supporter of combustion ; invisible ; inoderous ; sour-tasted ; possesses acid properties ; heavier than air ; eagerly absorbed by water ; great decomposing agent, especially of rocks ; generated by decay of animal and vegetable matter, Combustion and Respiration ; a constant admixture of Air ; absorbed by the leaves and roots of plants ; composed of Carbon and Oxygen ; gives Carbon to vegetables.

7. Water : exists in five states ; heaviest at 40° ; absorbs heat when its form is changed from a solid to a fluid, or fluid to a vapour : dissolved by Air in proportion to the temperature ; upon condensation forms clouds or mists, and, when condensed on the surfaces of bodies, dew ; possesses a great solvent power for gases and solids ; pure Water is most conducive to animal health, also to domestic and manufacturing economy ; composed of the gases Oxygen and Hydrogen ; decomposed, and its elements assimilated by plants ; Water is the great agent in conveying solids and gases into the system of

plants by their roots ; it is exhaled by the leaves and stems.

8. Ammonia : formed in Air by the action of Lightning, also by the decomposition of vegetable and animal bodies containing Nitrogen ; composed of Hydrogen and Nitrogen ; eagerly absorbed by water, clay, vegetable mould ; enters plants by their roots, and is the main source of their Nitrogen.

9. The ultimate results of the decomposition of organized bodies are Carbonic Acid, Water, Ammonia, and a minute quantity of Ash. "Thus, the destruction of one generation becomes the means for the production of a new one."

# LECTURE II.

General Structure of Vegetables—Transmission of Water through Vegetables—The Soil—Substances common to Soils and Vegetables—Action of Water on Soils—Inorganic Food of Vegetables—Sulphur, Phosphorus, Potash, Soda, Magnesia, Lime, Flint, Iron, Chlorine, and Iodine—Flint, Lime, and Potash Plants—Table of Mineral Substances abstracted by Crop—Analysis of a "worn out" Soil—Analysis of a Fertile Soil—Vegetable Matter in Soils—Recapitulation.

39. The general structure of a vegetable is admirably adapted to the conditions under which it exists. Its leaves are continually bathed in an atmosphere containing the main source of its food, while its roots repose in a soil where abundance of moisture is ready to convey into its interior those mineral ingredients which assist the plant in digesting and assimilating its atmospheric nutriment. The leaves are employed during the day time in incessantly searching from the moving air which agitates them the Carbonic Acid which supplies them with Carbon: the roots are engaged in drinking from the earth a copious supply of Water, containing Ammonia and solid substances in solution. These, the vital energies of the plant fabricate together, and form from their crude elements its varied and beautiful tissues.

40. The extremities of the fibres, or lesser roots of vegetables are similar in their construction to a sponge; hence, called *spongioles*. They consist of a soft substance, containing a number of exceedingly small openings or mouths, through which water, and whatever solids are dissolved in it, is alone capable of entering. It is thus that imbibed water forms the means of introducing into vegetables

various mineral substances, which are absolutely necessary to their growth, and which could not enter into them in a solid state, however finely divided. During the winter months important additions are furnished to the ends of the roots, in the form of new spongy extremities, or spongioles, which enable them to commence early and active absorbing operations in the first warm days of spring. The spongioles, or mouths of the roots, are connected continuously with the leaves by means of the tubes of the stem, which may be distinctly seen by the unassisted eye in the partially decayed wood of trees, in reeds and other water plants, also in vines and canes.

41. The quantity of water transmitted through the system of plants is immense. From the leaves of a well-wooded acre of land, not less than three hundred thousand gallons pass off in the form of invisible vapour during the four months intervening May and October; and at the lowest computation, an acre of wheat, just before flowering, daily exhales five tons of water. We thus see how easily disease in vegetables may be engendered, when evaporation from their leaves is suppressed by any external cause. We have, indeed, but too abundant examples of the baneful effects of suppressed evaporation in the potato disease, rust on wheat, mildew, and sunburn.—(See Diseases of Vegetables, Art. 172, &c.)—The small mouths or pores through which evaporation of moisture takes place, are generally found in all parts of healthy plants, except the roots. When seen through a microscope, they present the appearance of small slits, communicating with the vessels of the bark or rind. Their number on the leaves of some species of vegetables is very great. On one square inch of the leaf of the common

clove pink there are no less than 38,500 on the upper and under surfaces; on the under surface of the vine leaf 13,600, and on the under side of the common lilac there are 160,000 to the square inch. When young trees are transplanted, it is advisable to diminish the evaporating surface of the leaves, by cutting off some of the branches, otherwise the tree will suffer from the temporary loss of a portion of its roots, destroyed during the operation of transplanting. In such cases, a sufficient quantity of water cannot be drawn up from the earth by the diminished roots, to supply the consumption of a large evaporating surface of leaf.

42. We now arrive at another principle in Agricultural Chemistry, briefly enunciated as follows:—

BEFORE ANY SOLID CAN ENTER INTO THE COMPOSITION OF VEGETABLES, IT MUST BE IN A STATE OF SOLUTION IN WATER.

It is contrary to the results of careful observation to suppose that the roots of vegetables receive, without any discrimination, whatever solids may be presented to them in a state of solution in water. They seem, indeed, to possess a limited power of selecting those which are especially adapted to afford them nutriment; although it does not appear that they can exercise any control over the quantity of proper food which enters at their roots. They may, therefore, like animals, be destroyed or injured by an over abundance, which they are incapable of digesting or excreting with sufficient rapidity. A healthy cultivated plant must have access to a *properly-balanced* supply of organic and inorganic food. If too large a quantity of the first kind is presented to it, its leaves and stalks will be unusually large and gross; but no seed will be formed. If organic food is wanting, the plant will arrive at early maturity, and form seed; but its stalk and leaves (especially of the narrow leaved plants) will be stunted and shrivelled. Where the supply of mineral or inorganic food is very deficient, the leaves of grain-producing plants may be well developed, but their seed will be comparatively worthless.

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## The Soil.

43. The uniform constitution of the atmosphere differs widely from the heterogeneous mixture we meet with in soils, which are as variously compounded as the rocks upon which they repose. The elements forming common air are few in number, and simple in character. The substances we find in soils are frequently numerous, and often complex in their constitution. All soils spring originally from the disintegration and decomposition of solid rocks; the agents most active in effecting these changes are Water, Temperature, Carbonic Acid, Oxygen, and Vegetables themselves.

44. Various bodies are found in soils which do not enter into the composition of vegetables. In an elementary view of Agricultural Chemistry, we do not require to enumerate their properties, without their presence effects such a change in the relations of the soil to temperature and moisture, as seriously to affect the growth of vegetables. It will be sufficient for our present purpose if we consider the relation to vegetable life of certain ingredients

which necessarily enter into their composition, and invariably form part of fertile soils.

45. The transmission of water, containing mineral ingredients in solution, through the roots and stems of vegetables, and its partial escape at the leaf, in its pure and gaseous state, furnish us with the remarkable mode in which dissolved solids are conveyed into their interior, and made to assist in the formation of their different organs. These solids are ten in number, and are named, respectively,

1. SULPHUR; 2. PHOSPHORUS; 3. POTASH; 4. SODA; 5. LIME; 6. MAGNESIA; 7. IRON; 8. FLINT; 9. CHLORINE; (a gas,) 10. IODINE.

Water possesses the property of dissolving small quantities of these bodies; all, with the exception of Iodine, are required by land plants, and they constitute what is termed the 'Ash,' when vegetable substances are burned in the open air; they are also termed, the INORGANIC elements of vegetables. (art. 35.)

46. The quantity of ash found in cultivated vegetables varies remarkably with the nature of the soil, and the species under examination. It is evident that every fertile soil contains the constituents of ash in abundance, also in *such a state*, that enough for the wants of the growing crop ARE SOLUBLE IN WATER, in order that they may be conveyed into the interior of the vegetable.

The waters of rivers, springs, and wells always contain a small quantity of various solids in a state of solution. By washing a soil repeatedly with pure rain water, we find that each time of washing the quantity of some of the substances dissolved is diminished, until, at length, no portion is taken up.

47. The London Board of Health examined 424 different specimens of water, from different parts of England, of which examinations the following are the results:—

1. Wells and springs, (294 specimens,) average number of grains of lime per gallon 25.36.

2. Rivers and brooks, (111 specimens,) average number of grains of lime per gallon 13.05.

3. Land and surface-drainage, (19 specimens,) average number of grains of lime per gallon 4.94.

It is evident that a large supply of soluble substances cannot exist in ordinary soils exposed to rain, snow, and dew. Every little stream is bearing its load of dissolved materials to that great storehouse and depository, the Sea. The continual action of rains washing out the soluble portions, and either conveying them altogether away, or transporting them into the subsoil below, coupled with repeated cropping, without the return of one particle in the form of manure, must, in the long run of years, render the most fertile soil destitute of soluble mineral substances, and consequently unfruitful. The quantity yearly abstracted by these means may be perfectly insignificant, when compared with the abundant store remaining behind: that small quantity, nevertheless, is of vital importance; for, although there may be thousands of tons of sulphur, potash, soda, &c., present in the soil, yet, IF NO PORTION BE SOLUBLE IN WATER, the soil, with reference to immediate agricultural purposes, is absolutely barren.

48. The analysis of a good crop of wheat, or any other cultivated vegetable, will exhibit the quantity of solid ingredients abstracted from the soil during its growth, and conveyed away in the straw and grain, or in the roots.

A crop of twenty-five bushels of wheat to the acre contains about 200 lbs. of solid mineral ingredients; an average crop of clover from 250 to 300 lbs.; and one of potatoes, including both roots and tops, upwards of 400 lbs. of solid mineral ingredients.

49. These quantities appear to be small, but when we consider that in many parts of this Province little return is made in the form of manure, that crop after crop of the same kind of vegetable is often grown for years together, and that rains are continually washing out, and streams and rivers bearing to the sea, the soluble ingredients of the soil: when we associate these considerations with the circumstance, that it requires many months, and even years, for temperature, moisture, and air to render soluble in water a sufficient quantity of each particular kind of ingredient required by growing crops, we cannot be surprised that complaints are made of diminishing scales of produce.

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## MINERAL, OR INORGANIC FOOD OF VEGETABLES.

50. SULPHUR.—Certain organs or parts of plants require for their formation a small amount of sulphur. It is of no importance to know, at present, the name and disposition of those organs; the bare fact that the presence of sulphur is absolutely necessary, will determine the agriculturist in investigating the subject.

| | | | | | | |
|---|---|---|---|---|---|---|
| In 10,000 lbs. | of | the ash of | Wheat | there were found | 12 lbs. | sulphur. |
| do. | " | " | do. Straw, | " | 40 " | " |
| do. | " | " | Oat Grain, | " | 40 " | " |
| do. | " | " | do. Straw, | " | 90 " | " |
| do. | " | " | Hay, | " | 151 " | " |
| do. | " | " | Vetch, | " | 170 " | " |
| do. | " | " | Peas, | " | 171 " | " |

These numbers vary with the nature of the soil; they serve, however, to show the *kind* of plants which require much sulphur, to which may be added hops, asparagus, sugar cane, the grape, black and white mustard, turnips, tobacco, &c. Wheat, barley, rye, and Indian corn require comparatively little sulphur.

51. The most common and widely-extended source of sulphur in soils is doubtless Gypsum, or Sulphate of Lime. (Sulphuric Acid or Oil of Vitriol, combined with Lime.) A barrel of *unburned* Gypsum, weighing 200 lbs., contains 36 lbs. of Sulphur, 33 lbs. of Lime, 42 lbs. of water, and 54 lbs. of Oxygen. A barrel of *burned* Gypsum, of the same weight, and in that condition in which it is used for farming purposes, contains 47 lbs. Sulphur, 83 lbs. Lime, and 70 lbs. Oxygen; the water which exists in it, in its natural state, being driven off by heat. The only advantages to be derived from burning Gypsum are to be found in the dimunition of space required for packing it, when about to be conveyed to a distance, and the greater ease with which it can be submitted to the grinding process. It is advisable to have Gypsum in the form of a powder, since in that state it can be more uniformly distributed over the crops, but its value as a manure is not increased by the operation of burning.

52. Gypsum is slightly soluble in water; one pound of Gypsum requiring 160 lbs. of water for its solution. Its effects, when spread upon the land, are greatly increased by mixing with it an equal quantity of common salt, before sowing. The quantity of Sulphur annually taken from the soil in Canada is enormous. A very insignificant portion ever finds its way back to the soil, on account of its being bound up in those materials which rarely swell

the manure heap. This useful substance is found in considerable quantities in the wool of sheep, in the hair and skin of animals generally, and it is also invariably met with in urine.

53. In 1848, Canada exported 3,500,000 bushels of wheat, which probably contained of sulphur no less than 252,000 lbs.; in the same year she raised 2,339,756 lbs. of wool, which, with the wasted urine, &c., contained at least an equal amount, making a sum total of half a million pounds of Sulphur abstracted from the soil, without the possibility of one particle being returned to it from those sources, in the form of manure.

54. PHOSPHORUS.—Phosphorus is found in the seeds of most vegetables, especially those cultivated for food. A very large quantity is annually taken from the soil. In 1847-8, Canada exported in the grain of wheat not less than 733,500 lbs.

When Phosphorus is burned in the air, it emits a very copious volume of white smoke, which consists of Phosphorus combined with Oxygen. The white smoke may be collected and dissolved in water. It has a sour taste, is therefore an acid, and is named Phosphoric Acid. Now, when Lime, Potash, Soda, Magnesia, Iron, &c., come in contact with Phosphoric Acid, a union takes place, and a number of new bodies are formed, which all go by the general designation of Phosphates; thus, a compound of Phosphoric Acid and Lime, is called Phosphate of Lime; of Phosphoric Acid and Iron, Phosphate of Iron, &c.

55. Phosphoric Acid is always found in very minute quantities in primitive rocks, when sought for. Its detection is frequently a matter of some difficulty; it exists in

all soils, often, however, in a state of combination with other bodies, forming compounds which are very insoluble in water; it is also one of those substances which, like Sulphur, do not, under ordinary circumstances, find their way to the manure heap. Phosphorus is found in many parts of the animal frame, especially in the bones. England imports annually very large quantities of bones, for the purposes of manure. The bones are either crushed, or dissolved in Sulphuric Acid, and applied to the soil, chiefly in order to restore a small portion of the Phosphorus, which, during centuries of cultivation, has been washed away by rains, or abstracted by crops.

56. So far back as 1827, England imported 40,000 tons of bones, having a value of 600,000 dollars; in ten years the value of the imported bones increased to $1,273,000, and since that period (1837) a still greater increase has taken place in the trade; so much so, that many large vessels are now employed, in conveying from South and North America, and from various parts of Europe, the bones of animals, to fertilize the fields of England. The average annual value of the bones used in that country as manure is now estimated at upwards of four millions of dollars.

57. No grain crops can succeed in a soil destitute of a supply of Soluble Phosphates; and one pound of bones contains as much Phosphorus as is required by one hundred pounds of wheat. At the lowest calculation, enough phosphorus was exported from Canada, in the year 1847–8, to build up the bony frame-work or skeleton, of sixty thousand full grown men. Every good cow, in one year, abstracts from the soil as much Phosphorus as is contained in 80 to 100 lbs. of bones, much of which enters

into the composition of milk, and the remainder is generally lost in the urine, (art. 101.) Pure Phosphate of Lime (the substance which gives strength to the bones) is found in many parts of Canada, in certain rocks. The time may not be far distant when it will be profitable to collect and grind it, for Agricultural purposes.

58. Potash, Soda, and Magnesia.—These substances exist in variable quantities in all cultivated crops. Vegetables appear to possess a limited power of making indiscriminate use of them, especially of Potash and Soda, when a supply of the latter substance can be obtained, (see art. 109.) This is not the case with Sulphur and Phosphorus; no seed nor *nutritious* juice can be formed without definite quantities of each. A few examples will serve to illustrate the very variable quantities in which Potash, Soda, and Magnesia are introduced into wheat. In six analyses of wheat, made by celebrated chemists, there were found in 100 lbs. of the Ash, in

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| No. 1. | 26 | lbs. | Potash. | No. 4. | 21¾ | lbs. | Potash, |
| | 6¼ | do. | Magnesia, | | 9½ | do. | Magnesia, |
| | ½ | do. | Soda. | | 15¾ | do. | Soda. |
| No. 2. | 30 | do. | Potash, | No. 5. | 24 | do. | Potash, |
| | 16¼ | do. | Magnesia, | | 13½ | do. | Magnesia, |
| | 0 | do. | Soda. | | 10¼ | do. | Soda. |
| No. 3. | 33¾ | do. | Potash. | No. 6. | 6 | do. | Potash, |
| | 13½ | do. | Magnesia, | | 13 | do. | Magnesia, |
| | 0 | do. | Soda. | | 28 | do. | Soda. |

59. Red Clover, Potatoes, and especially Potato tops, Beetroots, Mangel Wurtzel, and Peas, in a word, most green crops, require much Potash or Soda, and Magnesia.

A comparatively small quantity of these substances will satisfy grain-producing crops.

| | | |
|---|---|---|
| An acre of Clover abstracts from.......... | 90—100 lbs. |
| do. of Beetroot or Mangel Wurtzel.. | 80—100 do. |
| do. of Potato tops......................... | 130—150 do. |
| do. of Grain and Straw of Wheat.... | 30—50 do. |

The large quantity of Potash, or of Potash and Soda, in Potato tops, contradicts the impression frequently found to prevail, that they are of little use as manure.

60. Lime.—A very important constituent of all vegetables cultivated for the food and use of man, and, if possible, an equally important agent in the hands of the Agriculturist, for ameliorating the condition of many kinds of soil. Its effects, as a manure, will be considered under that head; it is sufficient for our present purpose to become acquainted with those kinds of vegetables which particularly require lime for the due formation of their various organs.

| | | | | |
|---|---|---|---|---|
| An acre of Clover abstracts | from | 70—90 | lbs. | of Lime. |
| do. of Hay, | do. do. | 30—50 | do. | do. |
| do. of Wheat Straw | do. | 15—20 | do. | do. |
| do. of Oat Straw | do. | 10—18 | do. | do. |

Various vegetables possess the power of assimilating more than an average quantity of Lime, if presented to them in a proper form. Its effects upon the straw of grain-producing crops are very remarkable, as will be shown in the sequel.

61. Farmers are acquainted with Lime in three different states,—1st, in the form of common Limestone, which consists of Lime and Carbonic Acid: 44 lbs. of Carbonic Acid and 56 lbs. of pure Lime, forming 100 lbs. of common Limestone. When burned in a kiln, Limestone

parts with its Carbonic Acid, and then constitutes, 2nd. quick or caustic lime; 3rd, in the form of slacked lime. When 9 lbs. of water are thrown upon 28 lbs. of caustic lime, the lime swells, evolves great heat, and entering into combination with the water, produces 37 lbs. of slacked lime. Lime is generally found in the soil in the state of Carbonate of Lime; that is to say, combined with Carbonic Acid. Its presence is indicated by effervescence when a strong acid is poured over it. In the burned, or caustic state, it possesses very powerful properties, causing the rapid decomposition of vegetable and animal substances.

62. FLINT.—Called by chemists Silica, composes a large proportion of the ash in all grain-producing plants; its office in vegetables is to give strength to those parts which seem particularly to require additional aids. The wheat plant affords an admirable illustration of elegance in form, combined with wonderful strength. A column 576 feet high and 3 feet in diameter, bearing a weight upon its summit equal to that of the column itself, represents a multiple of a wheat plant four feet high and one-fourth of an inch in diameter. No selection of materials, or contrivance in binding them together, would enable an artificial structure of these proportions to resist the force exerted by a gentle breeze.

63. A good crop of Wheat, from one acre, abstracts in the straw alone from 120 to 150 lbs. of Flint; of Oats, seed and straw, from 40 to 60 lbs.; Mangel Wurtzel and Beets, from 12 to 18 lbs. of Flint.

64. IRON.—Iron is present in all fertile soils, and is also an invariable constituent of vegetables. It greatly increases the tenacity of clays, when found in the soil in the state

of black Oxide or black rust of Iron, a substance composed of Oxygen and Iron ; it may be converted into the red Oxide or common rust by exposure to the Oxygen of the air. Red Oxide of Iron differs from the black Oxide, in containing a larger quantity of Oxygen. The black oxide is soluble in water, and prejudicial to vegetables ; the red oxide is sparingly soluble, and a harmless or rather useful product. Iron is found in all the clay soils of Canada, in the form of the black Magnetic Oxide of Iron: on the shores of Lakes Ontario, Simcoe, Huron, St. Clair, &c., it occurs in very large quantities, mixed with white and red sand : it may be separated by means of a magnet.

65. CHLORINE.—This substance does not exist in a simple or pure state; it is always found in combination with other bodies : common sált is the great storehouse of Chlorine. Salt is composed of a metal Sodium in union with Chlorine. When used as a manure, salt yields Soda and Chlorine to vegetables. Chlorine exercises a remarkable influence on the germination of seeds.

66. IODINE is only found in sea plants, or those growing in the immediate neighbourhood of salt water.

67. It will be observed that different kinds of cultivated vegetables require for their due formation, different quantities of Flint, Lime, Magnesia, Potash, and Soda. A variety of convenient and useful arrangements of vegetables can be framed on the basis of their respective requirements. Thus we have as a very general, and necessarily imperfect

method of arrangement, the following Flint, Potash, Soda, Lime, and Magnesia plants :—

| Flint Plants. | Potash and Soda Plants. | Lime and Magnesia Plants. |
|---|---|---|
| Wheat, | Turnips, | Peas, |
| Oats, | Beet-root, | Beans, |
| Rye, | Mangel Wurtzel, | Clover, |
| Barley, | Indian Corn, | Tobacco. |
| | Potatoes. | |

Hay partaking of the character of the three classes.—(Liebig.)

68. Other, and more exact modes of arrangement of different kinds of vegetables, with reference to each other, naturally suggest themselves, when the number under consideration is diminished; these will be introduced hereafter, under "Rotation of Crops." The table given on the next page is well deserving of consideration, as it serves to exhibit, in an admirable manner, the relative and absolute quantities of inorganic or mineral food taken from the soil, by different kinds of crops. The effect of a continued abstraction of mineral food, without any return being made in the form of manure, is shown in the present condition of New England, the older settled parts of the Canadas, &c. &c. (see art. 7.)

# TABLE OF MINERAL SUBSTANCES

## TAKEN UP FROM THE SOIL,

### BY THE VARIOUS CROPS GROWN (AT BECHELBRONN) UPON ONE ACRE RESPECTIVELY.

| | Dry Crop. | Ashes per Cent. | Ashes per Acre. | Phosphoric Acid. | Sulphuric Acid. | Chlorine. | Lime. | Magnesia. | Potash and Soda. | Silica. | Oxide of Iron, Alumina, &c. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Potatoes, ............ | 2,828 | 4.0 | 113 | 13 | 8.0 | 3.0 | 2 | 6 | 53 | 6 | 17.0 |
| Beet Roots, .......... | 2,908 | 6.3 | 183 | 11 | 3.0 | 9.0 | 13 | 8 | 82 | 15 | 4.75 |
| Potato Tops, ...... | 5,042 | 6.0 | 303 | 33 | 7.0 | 4.0 | 7 | 5 | 135 | 39 | 16.0 |
| Wheat, ............... | 1,052 | 2.4 | 25 | 12 | 0.3 | — | 0.8 | 4 | 7 | 0.4 | — |
| Wheat Straw,....... | 2,558 | 7.0 | 179 | 5 | 1.5 | 1.0 | 15 | 9 | 17 | 121 | 1.75 |
| Oats, .................. | 975 | 4.0 | 39 | 6 | 0.4 | 0.2 | 12 | 3 | 5 | 21 | 0.6 |
| Oat Straw, .......... | 1,176 | 5.1 | 60 | 1.5 | 2.5 | 3.0 | 5 | 15 | 17 | 24 | 1.0 |
| Clover, ........... ..... | 3,693 | 7.7 | 284 | 18 | 7.0 | 7.0 | 70 | 18 | 77 | 15 | 0.9 |
| Peas,.................... | 915 | 3.1 | 28 | 8 | 1.2 | 0.3 | 3 | 3 | 10 | 0.6 | — |
| Beans (Horse) ...... | 1,944 | 3.0 | 58 | 20 | 0.75 | 0.5 | 3 | 5 | 26 | 0.3 | — |

*Boussingault.*

69. The recent analysis of a soil (from the Seignory of Chambly, in Lower Canada, by T. S. Hunt, Esq., Chemist and Mineralogist to the Provincial Geological Survey,) "exhausted by having yielded crops of wheat for many successive years, without receiving any manure," gave the following results:—

In 100,000 lbs. of the soil there were found, of

| | | |
|---|---|---|
| Lime, . . . . . . . . | 317 | lbs. |
| Magnesia, . . . . . | 883 | ,, |
| Potash and Soda, . . | 330 | ,, |
| Sulphuric Acid, . . | 31 | ,, |
| Phosphoric Acid, . . | 126 | ,, |
| Soluble Flint, . . . . | 80 | ,, |

We here discover an abundance of all the necessary substances which plants require. The plea of deficiency, therefore, cannot obtain in this instance. The present barrenness of the soil is in a great measure due to the INSOLUBLE STATE in which some of those bodies exist at present, for the same soil, when subjected to the action of water, gave only minute traces of those substances, which analysis proved to be present in sufficient quantity for all the purposes of vegetables. This view is confirmed by the remark of Mr. Hunt, that it supported nothing but "a scanty growth of a short wiry grass, which is regarded as indicative of an impoverished soil, and known as *herbe a cheval.*" This specimen of soil was taken from a depth of six inches, and contained $6\frac{8}{10}$ per cent. of vegetable matter.

70. We have had under consideration a soil which at

one period was eminently fertile, having yielded successive crops of wheat for thirty years; at present, however, barren, and yet possessing in abundance a supply of all needful substances for thousands of crops of wheat, or any other vegetable which, at the pleasure of the cultivator, might be grown upon it. The above example affords a good illustration of the condition of other soils which have been subjected to an injudicious course of cropping.

The following table exhibits the relative quantities of mineral substances dissolved out of a rich black mould, taken from the Flats of the Grand River, by the application of hot Hydrochloric Acid:—

100,000 lbs. of the soil would have yielded to the acid, of—

| | | |
|---|---|---|
| Lime, . . . . . . . . . . . . . | 5200 | „ |
| Magnesia, . . . . . . . . . . . . | 3460 | „ |
| Potash, . . . . . . . . . . . . . | 160 | „ |
| Sodà, . . . . . . . . . . . . . . | 190 | „ |
| Phosphoric Acid, . . . . . . . . | 300 | „ |
| Sulphuric Acid, . . . . . . . . | 90 | „ |
| Soluble Flint, . . . . . . . . . | 220 | „ |

One hundred pounds of the soil were composed of the following materials:—

| | |
|---|---|
| Sand, . . . . . . . . . . . . . | 72 lbs. |
| Finer Material, . . . . . . . . . | 20 „ |
| Vegetable Matter, . . . . . . | 6.5 „ |
| Water, . . . . . . . . . . . . . | 1.5 „ |
| | 100 lbs. |

If we suppose that an acre of each of the soils adverted to in articles 69 and 70, to the depth of 10 inches, weighed 1000 tons, the quantity of available Phosphoric Acid, Sulphuric Acid, and Soluble Flint present in them would be thus represented :—

| | Rich Black Mould. | Exhausted Soil. |
|---|---|---|
| Phosphoric Acid, . . . | 6000 lbs. | 2500 lbs. |
| Sulphuric Acid, . . . | 1500 lbs. | 650 lbs. |
| Soluble Flint, . . . . | 4100 lbs. | 1600 lbs. |

It is to be understood that these numbers represent the approximate amount of the ingredients capable of being abstracted by that powerful solvent, hot Hydrochloric Acid (Spirit of Salt).

The quantity of the above-mentioned acids abstracted by cropping the now exhausted soil, for thirty years, with Wheat, would be about—

| | |
|---|---|
| Phosphoric Acid, . . . . . . . | 510 lbs. |
| Sulphuric Acid, . . . . . . . | 52 ,, |
| Flint, . . . . . . . . . . . . . | 3612 ,, |

The quantity of vegetable matter in both soils is the same. It will therefore appear evident that the exhaustion or barrenness of the Lower Canadian soil is mainly produced by an insufficiency of *soluble* food, and the cause of that insufficiency is traced to the abstraction (without any return in the form of manure) of soluble mineral ingredients faster than atmospheric agents could prepare a supply for solution in water, from the store which still exists in insoluble abundance in the soil.

71. In the parish of St. Dominique, and in the neighbourhood of St. Hyacinthe, (Lower Canada,) there in an extensive peat bog, covering an area of about 20 square miles, and of a debth varying from 3 to 6 feet. When the bog is drained, it is burned to the debth of eight or ten

inches, and leaves a layer of redish ash. "This serves as a powerful manure, and the peat will then yield one or two fine crops of barley or oats; the straw attains an astonishing size and strength, and the grain is equally very superior. The burned soil produces also fine potatoes and turnips; but after two years it is found to be quite exhaused, and requires to be again burned to render it productive. When by many repetitions of this process, the peat has been burned down to within a few inches of the clay, the two are mixed by deep ploughing, and a rich mellow soil is obtained, which is unsurpassed for wheat, and yields at the same time fine Indian corn, peas, and grass. The peat ash contains more than two per cent of phosphate of Lime or bone earth, more than fifteen per cent of Gypsum. More than sixteen per cent of the ash are SOLUBLE IN WATER, and the rest is in such a minutely divided state, that it is soon removed from the surface of the porous peat, *being drained off by the atmospheric waters;* hence the rapid deterioration of the fertile soil, which is attained by burning the surface; once, however, reduced so near the clay, as to be mixed with it in ploughing, the ashes are retained, and enrich very much the clay subsoil." (Report on the Geological Survey of Canada.)

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### VEGETABLE MATTER IN SOILS.

72. All fertile soils contain a variable quantity of vegetable matter, derived from decayed and decaying roots and leaves. The Carbon contained in vegetable matter slowly combines with the Oxygen of the air, and forms Carbonic Acid, which is absorbed by water, and thus taken by the roots into the system of growing vegetables. It is

chiefly from this source that they derive their supply of Carbonic Acid, before they have thrown out many leaves. "EACH NEW LEAF FURNISHES THEM WITH ANOTHER MOUTH AND STOMACH."

73. The power which plants possess of absorbing Carbonic Acid from the atmosphere is proportionate to the surface of the leaves. STRAIGHT AND NARROW LEAVED PLANTS, those which are grown for their seed, as Wheat, Rye, Oats, Barley, depend more upon the soil for their supply of Carbonic Acid, than the Jerusalem Artichoke, the Mangel Wurtzel, or the Beet-root, which are grown for the sake of their roots. The great size of the roots, stalks, and leaves of the root crops would lead us to suppose that they contained a much larger quantity of Carbon than the grain-producing crops: this is not strictly the case, and the reason is found to lie in the fact, that roots of Turnips, Mangel Wurtzel, Beets, and Potatoes contain from 700 to 900 parts of water in 1000 of the fresh roots; whereas the quantity of water in grasses and grain varies from 120 to 150 pts. in the thousand. It is thus that grain crops *exhaust* the soil of vegetable matter, and consequently of the means of supplying Carbonic Acid to succeeding young plants; they take more Carbon from the soil than they leave behind, in the form of decaying roots and stubble.

74. The roots of Clover, the grasses, and the leaves of Turnips, Mangel Wurtzel, &c., which are usually left upon the land, contain more Carbon than the whole of the crop abstracted from the soil during its growth. A judicious rotation of crops, one in which the broad-leaved plants occupy a prominent place, leaves the land *richer* in vegetable matter than before the rotation began. The atmos-

phere supplies the Carbon in the form of Carbonic Acid, the vegetable, under the influence of light, combines it with the elements of water, and forms woody fibre, of which the roots, leaves, and stalk are chiefly composed. The roots being left in the soil, slowly decay, and restore to the air or to other growing vegetables, the Carbonic Acid originally withdrawn by the leaves. We thus observe that Wheat grown on peaty soils, or soils rich in vegetable matter, has a rank and luxuriant leaf, while crops grown on sandy soils, or soils destitute of organic food, are often stinted in their growth.

Vegetable matter diminishes very rapidly in the soils of Canada. This is due to the high temperature and comparative humidity of the summer months, whereby decomposition is promoted, and the conversion of the remains of plants and trees into Carbonic Acid, water, &c., effected in consequence. Every practical farmer must have remarked how the colour of a newly-cleared soil *pales* after a few years cropping, under the system of husbandry commonly pursued in this country.

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RECAPITULATION.

10. A Plant consists essentially of four parts, the stem, the root, the leaves, and the seed. The root may be considered as the downward extension of the stem; it consists of two parts, the main root, whose office is to sustain the plant in the soil, and the radicles, which imbibe nourishment from it.

11. The Leaves may be considered as an upward expansion of the stem; their office is to draw nourishment from the atmosphere, and assist its digestion, by exposing

the sap to the influence of air, light, and heat; also to give off gases and vapour of water.

12. The extremities of the radicles, and the under surfaces of leaves, are porous. The pores of the leaves serve as mouths, for the absorption and exhalation of gases and water, and as stomachs for their digestion. In some plants, the upper surfaces of the leaves are porous, yet generally covered with a resinous exudation.

13. The extremities of the radicles act also as mouths, to absorb gases and solids in a state of solution in water. They serve also to excrete sap and substances which are not required by the plant. Both roots and leaves, especially the latter organs, exercise a discriminating power in the reception of food.

14. All solid substances must be in a state of solution in water, before they can enter into the system of vegetables. Those which are necessary for cultivated plants are nine in number; they are S. Ph. Po. So. L. M. I. F. and Cl.

15. All fertile soils must have a supply of these solids in a soluble state, for the use of growing vegetables. Ordinary husbandry, in Canada, tends greatly to lessen that supply, and, consequently, to lead to diminishing scales of produce.

16. All fertile soils must contain a supply of vegetable matter, in order to furnish organic food, to be taken up by water, through the roots of plants, thus assisting the leaves in their search for nutriment; their field of operations being necessarily limited to the atmosphere.

17. The narrow-leaved grain-producing crops diminish the quantity of organic food in the soil; root crops, and broad-leaved plants generally, increase the quantity of

organic food in the soil, drawing it from the atmosphere, and leaving it in the form of decaying roots and leaves.

18. All cultivated vegetables, when taken off the land, diminish the supply of soluble inorganic mineral food in the soil, and will eventually render it barren for a time, if nothing is returned in the form of manure.

# LECTURE III.

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Artifices for Ameliorating the Condition of the Soil—Ploughing—Draining — Evaporation and Filtration—Fallowing—Rotation of Crops—Rotation Courses—The Sap—Ascent and Descent of the Sap—Recapitulation.

75. Experience proves beyond doubt that a continuance of that method of cultivation, which prevails to a very large extent in Canada and the United States, must result in a general deterioration of the soil subject to such objectionable culture, (art. 7 and 9.) It is already a matter of great moment to practical farmers in Canada, to ascertain the exact nature and rationale of the artifices they must employ in order to restore and render permanent the fertility of impoverished soils, and to preserve or increase the natural productiveness of those which are yet unimpaired. Those artifices are comprehended in the operations of PLOUGHING, DRAINING, FALLOWING, ROTATION of CROPS, and the application of MANURES.

76. PLOUGHING.—The beneficial effects produced by ploughing are mainly due to the free circulation that operation gives to air among the particles of the soil, whereby the decomposition and solubility in water of the mineral portion is greatly facilitated, as well as the conversion of decaying vegetable matter into Carbonic Acid, Ammonia, and Water. Air (that is the oxygen of air) is necessary to the germination of seeds; hence the reason why so many different kinds of weeds spring up when the soil is first stirred to the depth of six or eight inches, the

dormant vitality of the seeds being revived, under its powerful influence. Oxygen also, when in a state of solution in water, is absorbed by the roots of plants, and proves highly efficacious in enabling them to appropriate food; no absorption of Oxygen can take place when the soil, in a compact and dense condition, impedes the circulation of air around its particles. Ploughing cleanses the soil from weeds; and rendering it more porous, it permits the young and tender roots of plants to penetrate in search of food; it also facilitates the absorption of rain water.

77. Many clays contain a quantity of iron in the form of the black rust of iron, a substance noxious to vegetables; in the presence of air it is converted into the red rust of iron, a harmless compound, (art. 64.) The change in the character of the iron-rust destroys the stiffness and tenacity of the clays, and converts them into comparatively loose and friable soils. Farmers frequently skim the surface of their fields with the plough. It is evident, from the rationale of the operation, that the deeper the plough penetrates, the greater benefit is likely to result.

78. The greatest surface of the soil, in ploughing, will be exposed to the atmosphere if the furrow-slice be inclined to the level surface of the soil at an angle of forty-five degrees. In order to effect this desirable object, a constant ratio must be maintained between the width and depth of the furrow-slice; thus, if the width be 10 inches, the depth must be 7 inches, in order that the angle of inclination may be 45 degrees; if 9 inches in breadth, the depth must be 6½ inches; if 8 in breadth, 5½ inches in depth; if 7 in breadth, 5 inches in depth; &c. &c.

79. The subsoil plough is much used in Great Britain;

it serves to break up and loosen the earth 10 or 12 inches below the limit to which the common plough penetrates. Subsoil ploughing is of little avail on soils possessing a retentive bottom, without thorough draining.

80. Draining.—The extensive introduction of a proper system of draining constitutes, unquestionably, the great modern improvement in the Art of Agriculture.

Its effects are due,

1st. To the greatly increased porosity of drained soils, allowing the circulation of air among their particles, with every change of temperature.

2nd. To the rapid removal of superfluous and stagnant water, which, on undrained soils, fills the pores or small spaces between their solid particles, and opposes the introduction of air into its place.

3rd. To the alteration which takes place in the mechanical composition of the soil, whereby it is rendered loose, friable, more easily worked, and at an earlier period of the year than when undrained.

4th. To the great change it produces in the temperature of the soil.

5th. To the greatly increased opportunity it affords soils of bringing into action their chemical powers. (art. 113.)

81. Recent experiments have satisfactorily established, that the evaporation of one pound of superfluous or drainage water, that is, of one pound of water over and above the quantity which a soil is capable of retaining by its power of attraction or absorption, lowers the temperature of the soil ten degrees. If the one pound of water pass off by the drains, and not by evaporation, no reduction in temperature takes place.

82. The mean highest temperature of the air in March (the earliest agricultural month in Canada) is 54°. The warm sun melts the snow and frozen surface of the soil. If thoroughly drained, the water will slowly filter to the drains during some hours of the day-time, and air, at the temperature of from 50° to 54°, *will follow the water*, thawing, before it is cooled, much frozen soil. In April, the mean highest temperature is 71°, the mean temperature 42°. During many hours of the day, warm air on drained soils will follow the water, and rapidly impart much of its warmth around and below the young roots of plants, thus inducing an early and rapid growth in that very important part of the plant.

83. Experiments have been made in England on the temperature of undrained soils; they exhibited the singular and very important fact, that the temperature of a wet soil *never* rose during many months above 47°, seven inches below the surface. The same soil, when drained, indicated a temperature, after a thunder-storm, of 66°, at 7 inches below the surface; and at a depth of two feet seven inches, a temperature of 48°. The mean or average temperature of a drained soil in the neighbourhood of Toronto, at the depth of three feet, is about 56°; during the months from May to October, both inclusive, the mean temperature at the depth of six feet, of a drained soil, is about 53° during the same period of time.

On undrained soils immense damage is done to fields by surface water washing off manure and fine particles of the soil, and conveying these important constituents to the water-courses and rivers. A very large quantity of the rain-fall escapes over the surface in this country, where the precipitation is comparatively violent. On properly drained farms, the surplus water alone would be carried away by the drains, and in nearly a pure state, except in cases of extraordinary rain-fall. (see art. 47.) Evaporation plays an astonishing part in removing the surplus water during the summer months. Its action during the winter months is proportionately small.

The following results of Dickenson's Dalton rain-guage will show the summer and winter effects of evaporation and filtration on one acre, near London, England :—

*Mean from April to September, inclusive.*

| Rain in Inches. | Filtration in Inches. | Evaporation in Inches. | Rain in Tons, Filtered. | Rain in Tons, Evaporated. |
|---|---|---|---|---|
| 11·67 | 0 90 | 11·77 | 91 | 1192 |

*Mean from October to March, inclusive.*

| Rain in Inches. | Filtration in Inches. | Evaporation in Inches. | Rain in Tons, Filtered. | Rain in Tons, Evaporated. |
|---|---|---|---|---|
| 13·95 | 10 39 | 3 56 | 1052 | 360 |

We see, from the foregoing table, that during the warm summer months, the evaporation amounted to 1192 tons, and the filtration to 91 tons only ; whereas, during the cold winter months, the evaporation was 360 tons, and the filtration no less then 1052.

81. It is occasionally urged by practical farmers that thorough draining will not succeed in the hot and dry summer season of Canada. This is a mistake ; the roots of vegetables shun stagnant water ; they turn aside when their descent would bring them in contact with it. They will penetrate many feet into the soil if it be well drained. But what is the case with our Canadian fields ? When the roots of wheat or other vegetables begin to grow in the

spring months, they discover, at the depth of six or seven inches, a supply of stagnant water, which can find no escape but by cold-producing evaporation, (art. 160.) The roots are not only chilled, but absolutely prevented from penetrating deeper in search of nutriment; they cannot thrive when surrounded by drainage water; their growth is retarded, and their range limited; on a drained soil they strike directly downwards to the level of the drains, and in those depths they discover a supply of moisture in seasons of drought, springing up from below by means of capillary attraction, besides that which every porous soil possesses the power of absorbing from the atmosphere.

In Western Canada, subsoil draining draws out the properties of the clay soils which abound in the country, in a manner truly remarkable; and the artifice may be prosecuted without the adoption of any precautions whatever against winter frosts. It is equivalent, as far as relates to the working of the soil, to an addition of three weeks or a month to the agricultural season for out-door operations. The writer had opportunities of observing the effect of winter frost upon the water issuing from the mouths of two long subsoil drains during the last winter. One of the drains in question was constructed in a clay subsoil, situated in the neighbourhood of the City of Toronto. The soil was first dug out to the depth of two feet; the opening being about 15 inches in breadth at the top, and 12 inches at the bottom. The drain was then made by digging a narrow water course, about 10 inches deep, and from 3 to 4 wide, in the retentive clay. On the shoulders thus formed, rough pine slabs were laid, and clay firmly stamped upon them. The remaining open portion was filled with the soil. The length of the drain was a third of a mile, and its depth varied from two feet ten inches to three feet six inches, owing to inequalities in the surface of the soil. Drainage water (nearly soft) issued from it copiously throughout the winter. The mouth was left quite exposed, and was roughly formed of two side slabs, with the upper shoulder slab resting upon them. The temperature of the water was tested frequently, and when a thermometer exposed to the air sank to zero, yet it never fell below thirty-four degrees when introduced into the water issuing from the drain, and was commonly about thirty-eight. The exposed water in the water course, at the mouth of the drain, was never frozen within fifteen or eighteen inches of the covered extremity. Another drain, constructed of road metal, in a rich vegetable mould, and having a depth of two feet six inches, and a length of two hundred and fifty yards, ran during the winter with precisely similar results.

85. "Different soils possess the property of absorbing moisture from the atmosphere in unequal degrees. During a night of 12 hours, and when the air is moist, according to Schübler, 1000 lbs of a perfectly dry,

| | |
|---|---|
| Quartzy Sand will gain . . . . . . . | 0 lbs. of water. |
| Calcareous Soil . . . . . . . . . . . | 2 do. |
| Loamy Soil . . . . . . . . . . . . . | 21 do. |
| Clay Loam . . . . . . . . . . . . . | 25 do. |
| Pure Agricultural Clay . . . . . . | 27 do. |

And peaty soils, or such as are rich in vegetable matter, a still larger quantity." We discover in this property the reason why potato plants always appear refreshed in dry weather after the earth has been stirred by the hoe round about their roots. The soil is thus made more porous; in effect a much larger surface is exposed to the air and the moisture it may contain; the moisture is absorbed, and ministers to the growth of the drooping plants.

86. Some soils possess the power of retaining a larger quantity of water than others. Clay exhibits this property in the most eminent degree. It is thus that vegetation on clay lands which have been well drained, is more luxuriant and fresher in dry weather than on lighter soils. The water retained by the soil, *i. e.*, that which does not pass off by the drains, or disappear in the subsoil, is called the *water of attraction*. The following table exhibits the quantity of water different kinds of soil are capable of retaining, in opposition to gravity. The specimens are supposed to be first dried in an oven, then suspended by a string, and water poured slowly upon them; thus, from 106 lbs. of dry soil water will begin to drop, if it be a quartz sand, when it has absorbed . . . . . 25 lbs.

| | |
|---|---|
| Calcareous sand (lime sand) . . . . . | 29 do. |
| Loamy Soil . . . . . . . . . . . . . . . | 40 do. |
| Chalk . . . . . . . . . . . . . . . . . . | 45 do. |
| Clay Loam . . . . . . . . . . . . . . . | 50 do. |
| Pure Clay . . . . . . . . . . . . . . . | 70 do. |

*Johnston.*

When water of attraction slowly disappears during the process of evaporation, the soil contracts and occasions fissures; this effect is particularly observable on clay soils.

87. It has been ascertained by vegetable physiologists that roots cease to grow as soon as the plant begins to form the seed: its energies are then exclusively devoted to that object. The formation of the seed, in many kinds of cultivated grain-producing crops, begins in June, or

early in July. A dry summer parches the soil to the depth of five or six inches. The limited depth to which the roots have penetrated prevents them from obtaining a sufficiency of moisture, the crop consequently suffers from drought; a disaster which took place to a very large extent last year (1850), with respect to clover and hay, and if the dry weather had continued a fortnight longer, the labors and hopes of the farmer, in many parts of the province, would have been altogether defeated. Comparatively little damage would have been done on drained soils, for the roots of vegetables, following their own natural tendencies, would have been able to penetrate during the early spring months deep into the soil, and there find a supply of moisture, removed from the rapidly evaporating influence of a hot sun and a dry atmosphere.

88. The great obstacle to thorough draining in Canada is the *expense*, coupled with the low price of farming produce. Within a convenient distance from large towns, where a market for wheat, oats, hay, peas, turnips, and mangel wurtzel is generally to be obtained, this objection can scarcely hold good. The great increase in the average produce, the superiority of the sample, the early maturity of the crops, their comparative safety from the effects of drought and the fly, all support the presumption of a rapid and profitable return for an outlay of capital. In districts remote from markets, the expense of thorough draining constitutes an insuperable objection to its introduction. Much good can, however, be accomplished by clean open furrows 10 or 12 inches deep, and so cut that they may admit of a continuous fall of water through their whole length, so that no portion may remain in any

part of the furrow. An inclination of one foot in three hundred will be quite sufficient to cause an unbroken current, if the fall be quite uniform. The effect of drainage is thus stated in the report of the London General Board of Health: "It has been determined, by observation, that if the annual increase of trees on undrained land were 3 per cent., the increase on drained land would be 6 per cent.; and on land both drained and irrigated, no less than 12 per cent., or four times the amount of growth on undrained land."

Stephens says, in his book of the farm, "A conviction has been forced upon me, by long and extensive observation of the state of the soil, over a great portion of the kingdom, that the neglect of draining is the true cause of most of the bad farming to be seen; and that a single farm does not exist, not already drained, which would not be much better for draining."

89. Where the land lies low, very beneficial results will be produced by a drain dug to the depth of two feet, with here and there a hole to the depth of three and a-half or four feet; the holes and drain being filled up to within one foot from the surface, with stones from two to five inches in diameter, then covered with a sod, trampled down, and filled up with earth. It may here be remarked, that open drains, with an occasional under-ground drain, require more care in construction than is usually devoted to them. Thorough draining is an art in itself, and implies an acquaintance with the characteristics of springs, soils, and climate, besides a practical knowledge of levelling.

90. A recent writer on draining, possessed of thirty-six years' experience, closes his remarks with the following

caution. "Our parting words shall assure our readers, that every reputed case of failure in draining, which we have investigated, has resolved itself into ignorance, blundering, bad materials, and bad execution." The same writer recommends the use of pipes, having an inch or inch and half bore, with collars to lay over the joinings, and prevent dis-arrangement. Collars are short pipes, which slip over the joinings of two contiguous drain-pipes, and effectually prevent the uniformity of the juncture from being disturbed by 'faults' in the floor of the drain, or by an *upheaval*.

It has been computed, that not less than £4,000,000 sterling have been expended in draining in England during the last ten years, and that nearly one million acres has been subjected to the process.

91. FALLOWING.—A Fallow implies the repose of the soil, or in other words, TIME to permit AIR, WATER, and TEMPERATURE to convert a certain amount of insoluble ingredients in the soil into available food for plants. A naked fallow is deprecated by many practical agriculturists and agricultural writers; they consider it as so much land thrown away for a time, and propose in its stead a judicious rotation of crops. It is very questionable, however, whether a naked fallow is not *occasionally* absolutely necessary in this country, where the growth of weeds is extremely rapid; where the high price of labour is always an obstacle to many hands being employed upon a farm; and where turnips cannot be fed off the land as in Great Britain, or other green crops introduced at present on an extensive scale. An occasional naked summer fallow seems to offer to the Canadian farmer the most avail-

able and the cheapest method, at present, of cleaning his fields ; especially where numerous patches of uncultivated land, every road side, and every neglected farm is a nursery for Canada thistles, wild mustard, wild chamomile, chess, mullen, foxtail, burrs, and other noxious weeds. Green Fallow is a term used with reference to the cultivation of Wheat, Rye, Barley, and Oats, with the intervention of some green crops, as Vetches, Clover, Turnips, Peas, &c., between each grain growing crop. The principles it involves will be introduced under the head of,

92. Rotation of Crops.—The origin and constitution of some favoured soils, is such as to require the active operation of air for a very limited period, to enable them to offer an abundant supply of soluble mineral food for the purposes of vegetables, without any extended rotation of crops. Wheat, a flint plant ; and Tobacco, a lime plant, have been grown alternately on large tracts of land in Hungary, within the memory of man, without any application of manure. In many parts of Upper and Lower Canada, in the valley of the Thames and the Richelieu, Wheat has been taken from the soil for 40 and even 50 successive years ; the soil eventually becoming incapable of returning a profitable crop. The repose of a fallow, in the form of grass or clover, for a few years, restores its fertility. During the period of the growth of fallow crops, air, water, and temperature exert their decomposing influence upon the soil, and convert an abundance of mineral ingredients, present in the soil in an insoluble state, into soluble food for grain-producing crops.

93. The alternate growth of wheat and tobacco upon

the fertile soil of Hungary, presents us with an easy and familiar illustration of the benefits springing from a rotation of crops. Wheat requires a large amount of flint; tobacco an equal quantity of lime. While wheat is growing, lime is accumulating in the soil in a soluble state, for the use of succeeding crops of tobacco, and the growth of the tobacco acts as a fallow for the preparation of the soil for wheat, because tobacco does not require a large supply of those particular mineral ingredients which are essential to the growth of wheat; added to this, tobacco is a broad-leaved plant, and derives a large supply of the Carbon it requires from the atmosphere. Its decaying roots will restore to the soil the Carbon extracted by the narrow-leaved wheat plant. It will thus be seen, that the general principle of a rotation of crops lies in the cultivation of a Flint Plant one year, a Potash Plant the next, and a Lime Plant the third, and so on. The character of the soil determines whether one, two, three, or four years should intervene the introduction of different kinds of vegetables. The following table, given by Liebig, may afford an apt illustration of the relation of different varieties of vegetables to special mineral ingredients, and the mode in which a judicious rotation of crops may increase the fertility of the soil. In 100 lbs. of the Ash of the following vegetables, the proportion of Potash and Soda, Lime and Magnesia, and Flint, are given under their respective heads:—

| | | Pot. and Soda. | Lime and Mag. | Flint. |
|---|---|---|---|---|
| Flint Plants | Oats, straw and seed ... | 34 lbs. | 4 lbs. | 62lbs |
| | Wheat straw .............. | 22 " | 7 " | 61 " |
| | Barley, straw and seed | 19 " | 25 " | 55 " |
| | Rye Straw................ | 18 " | 16 " | 64 " |
| Lime and Magnesia Plants | Tobacco ..................... | 24 " | 67 " | 8 " |
| | Pea straw .................... | 28 " | 64 " | 8 " |
| | Potato Stalks.............. | 4 " | 59 " | 36 " |
| | Clover ........................ | 39 " | 56 " | 5 " |
| Potash and Soda Plants | Indian Corn ............... | 71 " | 6 " | 18 " |
| | Turnips ...................... | 82 " | 18 " | 0 " |
| | Beets ......................... | 88 " | 12 " | 0 " |
| | Potatoes (tubers) ......... | 85 " | 14 " | 0 " |

On sandy soils, and soils generally deficient in vegetable matter, that rotation of crops which *borrows most from the atmosphere*, and leaves the largest quantity of decaying matter in the soil, will be found the most productive.

91. After draining, no operation in the management of a farm requires so much forethought as the introduction of a proper rotation of crops. A number of rotations are given below, as *illustrations* of this important department of husbandry. It is, however, to be well observed that no general rule can be given. The rotation depends in a great measure upon the character and composition of the soil ; *also upon the markets*. A profitable practical rotation often differs widely from a purely theoretical one. Many obvious reasons will immediately present themselves to the practical farmer for this distinction : such as climate, local or general diseases, accidental peculiarity in the physical character of the soil, &c. &c.

ROTATION COURSE, No. 1.

1st year, Wheat (Flint Plant).
2nd do. Oats with Clover (Flint and Potash Plant).
3rd do. Clover for Hay (Lime Plant).
4th do. Grazed.
5th do. Grazed and broken up for wheat.

ROTATION COURSE, No. 2.

1st year, Fallow.
2nd do. Wheat (Flint Plant).
3rd do. Peas (Lime-Potash Plant).
4th do. Oats with Clover (Flint and Potash Plant).
5th do. Clover (Lime Plant).

ROTATION COURSE, No. 3.

1st year, Beet or Turnips (Potash Plants).
2nd do. Wheat (Flint Plant).
3rd do. Red Clover (Lime Plant).
4th do. Wheat (Flint Plant).

ROTATION COURSE, No. 4.

1st year, Turnips, or Mangel Wurtzel (Potash Plants).
2nd do. Wheat with Red Clover (Flint Plant).
3rd do. Red Clover (Lime Plant).
4th do. Clover Hay (Lime Plant).
5th do. Wheat (Flint Plant).

The following is not an uncommon Rotation north of Toronto:—

| | | |
|---|---|---|
| 1st year, . . . . . | Wheat | (Flint Plant) |
| 2nd do. . . . . . | Peas | (Lime-Potash Plant). |
| 3rd do. . . . . . | Wheat | (Flint Plant). |
| 4th do. . . . . . | Oats | (Flint Plant). |
| 5th do. . . . . . | Fallow. | |

[For further remarks on this important subject, see the close of Lecture VIII.]

95. Good Husbandry implies the elevation of the standard of fertility and production to the highest remunerative point, and its continuation there. A due attention to all the minutiæ of farming labour is far from being sufficient. Continued success, in these days of progress and competition, can never attend the most industrious farmer if he neglect the new precautions and artifices which experience and the science of Agriculture are continually suggesting. It is a fact, which rests upon the most abundant and conclusive evidence, that no ordinary farm can continue for a succession of years to yield a fair return, if attention be not paid to rotation of Crops, the application of manures, and, at least, to surface-draining. As a fair rule for guidance, in Canada, we may act with perfect confidence on this principle, that NO FARM CAN CONTINUE TO YIELD GRAIN-PRODUCING CROPS ON A GREATER SURFACE THAN ONE-THIRD OF ITS CULTIVATED EXTENT FOR MANY SUCCESSIVE YEARS, WITHOUT DIMINISHING SCALES OF PRODUCE; that is to say, a farm of fifty acres in the clear, and under cultivation, cannot sustain a larger amount of grain-producing crops than seventeen acres; or a farm of one hundred acres in the clear, and under cultivation, not more than thirty-four acres, producing at the same time high averages, and preserving their fertility undiminished.

96. That Canadian husbandry exhibits generally a marked neglect of this important principle, may be seen by an examination of the following tables of the distribution of crops over the whole cultivated extent of the country, reduced to the scale of 100 acres, when compared

with a similar reduction of the distribution of crops in England.

| Upper Canada, 1847. | England, in 1835. |
|---|---|
| 47 acres Flint Plants, | 21 acres Flint Plants, |
| 12½ " Potash-Lime Plants, | 12 " Potash-Lime Plants, |
| 36 " Pasture, | 58 " Meadow & Pasture, |
| 4½ " Fallow. | 9 " Fallow. |
| 100 acres. | 100 acres. |

The ratio which the grain-producing or flint crops bear to the whole hundred acres, are in,

Upper Canada........... 47 to 100, equal to one-half nearly.
England.................... 21 to 100, equal to ONE-FIFTH nearly.

97. We have seen that the food of vegetables consists of gases and solids, contained in air and the soil; also, that the gaseous food is extremely simple, and may be taken into the plant in two different ways; either by a discriminate absorption of Carbonic Acid from air by the leaves during the day-time, and of Oxygen during the night-time; or by the indiscriminate rise of water, containing Carbonic Acid, Ammonia, &c., and solids in solution, through the extremities or spongioles of the roots, to every portion of the plant, and constituting, after having gone through certain chemical changes,

## The Sap.

98. The general course of the sap in trees is from the roots, through the newer wood (the sap-wood), to an upper layer of veins in the leaf; it here loses much of its water by evaporation, and suffers certain chemical changes, due

to the influence of light. It then passes from the upper layer of veins in the leaf to another layer immediately beneath them, through small capillary tubes. From the lower layer of veins in the leaf it descends through the inner bark, towards the roots again. During its descent, it lays on new wood, and strengthens the vessels of the old wood, by filling them up with solid matter.

99. The continuous rise of the sap in plants is due to two forces—capillary attraction, and the pressure of the atmosphere. If no other force were called into operation but the attraction for water exerted by the sides of small tube-like vessels in the roots, stem, and branches, the sap would be drawn up to the highest part of the plant, and then remain motionless, there being nothing above it to draw it further up; yet, during the warm and dry weather of spring, summer and autumn, the sap continually ascends, and sometimes with great force and velocity. Its uninterrupted and rapid current is mainly due to the pressure of the atmosphere, which is called into action by the vacuum resulting from the great evaporation which takes place from the leaves, (art. 41.) The atmosphere, pressing upon the surface of the earth, forces the water contained in the soil through the roots, to fill the empty spaces occasioned by evaporation. When the supply of water is insufficient, as in seasons of drought, or at the close of a very hot day, the leaves droop, and frequently wither. In wet weather, on the contrary, evaporation from the leaf ceases; the sap is consequently incapable of rising; it stagnates, loses its vitality, decays, and forms a fertile soil for the growth of fungi. (art. 172.)

100. The cause of the descent of sap in vegetables is

more difficult to comprehend than its ascent. The following illustration may, perhaps, serve to explain the operation of its downward progress, or, rather, of its progress towards the roots; for, in the drooping branches of trees, it is evident that the sap in the inner bark frequently ascends, in a manner and under circumstances which are opposed to capillary attraction and gravity:—If we take a long glass tube, either straight or bent, tie round one extremity a portion of the intestine of an ox, sheep, pig, or any animal membrane, and pour a quantity of brine into the open end of the tube, then plunge the covered extremity into a glass vessel containing pure water, we shall soon observe the dense fluid in the long tube rise many inches above its original height; at the same time, the water in the glass vessel will diminish in quantity, but taste strongly of salt. The operation of DIFFUSION will continue until the fluid in both vessels attains the same density, and, consequently, the same degree of saltness. The height to which the fluid will rise in the long tube depends upon the nature of the membrane, and the relative quantities of brine and pure water employed in the experiment. Here, however, we have an example of what takes place in the vegetable fabric.

The porous substance of the leaves represents the porous animal membrane; the thin sap in the newer wood, the pure water in the vessel; the inner bark represents the long tube containing the brine; and the dense sap in the inner bark, (produced by continued evaporation from the leaves and bark.) the brine itself. It is clear that the sap in the bark will always be more dense than that in the inner wood, on account of evaporation from the exterior surface of all parts of the bark and leaves. The portion of the sap which is thus forced to the roots again is discharged. It is generally strongly charged with those substances which are formed in different species of vegetables. Thus, the soil in which poppies are growing will be found to contain opium; tannin is also found about the roots of the oak and hemlock, and resinous substances in the neighbourhood of balsams, pines, &c.

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## Recapitulation.

19. The prevailing farming practice in Canada and the United States, involves the abstraction of needful inorganic and organic food from the soil, without the due adoption of those artifices which can alone prevent its deterioration.

20. The design of those artifices are,

1st. To call into active operation the great agents, Air and Heat, by ploughing and draining the soil.

2nd. To give Time for their influences to be exerted beneficially, by the introduction of a judicious rotation of crops.

3rd. To restore, in the form of Manures, some of the elements of food abstracted by cropping.

21. Draining removes surplus water; renders soils porous; admits air and heat; permits the roots of plants to expand and ramify; deepens the available soil; elevates its temperature; makes it more easily worked; adds some

weeks to the season for out-door operations; brings into action the chemical powers of the soil.

27. Drains should never be less than 30 inches deep, and always under-ground. In light soils they should be constructed of tiles or pipes, the smaller the better, so that the orifice is not less than one inch in diameter. In heavy soils, road-metal (pebbles varying in size from one inch to five in diameter) may be used with success. In all cases, sod or stiff clay should be firmly stamped on the top of the pipes or road-metal In retentive clays, the drain described in art. 84 succeeds well. The narrower the water-course, the more permanent will be the drain.

## LECTURE IV.

Manures—Farm-yard Manure—Urine—Green Manuring—Mineral Manures—Gypsum—Salt—Lime—Marl—Leached Wood Ashes—Action of Soils on Manures—Surface Action—Experiments in England—Recapitulation.

### MANURES.

101. We cannot increase the amount of available vegetable food in air, nor can we always rely upon the presence of a sufficient supply of mineral food in the soil, capable of being dissolved by rain-water; we can, however, place abundance of both kinds of nutriment within reach of the roots, IN THE FORM OF MANURES. Whatever is added to the soil, for the purpose of increasing its fertility, is termed a *manure*. The object of the farmer, in the use of manures, is either to place within the reach of vegetables the substances they require to build up their structure, or so to change the nature of the soil, that its adaptation to cultivated plants may be increased. The most convenient mode of exhibiting the action of different applicable manures is to describe each separately, and state the effects they are capable of producing, and the object for which they are applied to the soil.

102. FARM-YARD MANURE is unquestionably the best kind for general purposes; it is easily accessible, and contains all the substances required by cultivated vegetables. The excrements of animals consist of a solid and

fluid portion: the fluid portion is far richer in saline and mineral ingredients, and in ammonia, than the solid portion. In 100 lbs. of the solid excrements of the horse, there is generally to be found about,

19 lbs. of Vegetable Matter,
3 do. " Saline and Mineral Ingredients.
78 do. " Water.

100 lbs.

The vegetable matter is slowly decomposed in the presence of air, and becomes converted into Carbonic Acid, Water, and Ammonia; the atmospheric food of plants.

103. In a ton of fresh horse manure we find about

400 lbs. of Vegetable and Animal Matter,
40 do. " Flint,
7 do. " Potash,
1½ do. " Soda,
¾ do. " Iron,
3 do. " Lime,
2 do. " Magnesia,
4 do. " Phosphorus,
¾ do. " Sulphur.

The older manure is, the less organic matter it contains, owing to decomposition and escape in the form of Carbonic Acid, Water, and Ammonia. What remains, however, will more speedily exercise a beneficial influence on vegetation, since its advanced stage of decay enables it to yield with rapidity a supply of organic food to growing crops; and, at the same time, the mineral ingredients will remain undiminished in quantity, without the manure-heap is exposed to rain, which will not fail to wash out both organic and inorganic materials as fast as they become soluble in water. The proper preservation of farm-yard manure is rarely practiced in Canada. Manure is frequently permitted to accumulate in the yard, or about the stables, and when required, it is at once conveyed to the field without any previous preparation.

As a general rule in Canada, manure should never be applied to the soil until it has undergone the process of thorough fermentation; otherwise, it will be scarcely possible to clear the land of many noxious weeds, whose seeds are scattered in all directions by every autumnal breeze, from those *extensive nurseries* on the road sides, where they are permitted to increase and multiply, to the great injury of neigbouring farms. Farm-yard manure should be piled in sheltered heaps, and occasionally moistened with its own drainage water, which should be collected and preserved for the purpose. A thin layer of loam, strewn over the dung-heap, is very effectual in retarding decomposition, and especially in fixing its gaseous products. (See art. 168, 169, and 170, for additional matter on the subject of farm-yard manure.)

It is not considered necessary, in view of the present state of Agriculture in Canada, to advert to the effect produced on the quality of farm-yard manure, by feeding animals with different kinds of food, as with oil-cake, &c., the main object is to induce farmers to apply accessible and cheap manure, with proper precautions: the prevailing farming practice being either to neglect the artifice altogether, or to make use of farm-yard litter and droppings without any preparation, and full of the seeds of weeds.

104. URINE.–The fame of guano, as a fertilizer, is spread throughout the world. Many farmers would consider the possession of a few tons as a surety for the success of future harvests. What is guano? The excrements of birds, composed of various saline and mineral ingredients, together with acids in combination with Ammonia, of which latter substance guano contains from 7 to 17 per cent. Its beneficial effects are due to the presence of Salts of Ammonia, and phosphates, in a soluble state. Canadian Farmers would not think of purchasing guano, even if a supply were at hand. The price of 40 to 60 dollars a ton presents an insuperable objection to its use as a manure for agricultural purposes, especially when a substitute of almost equal value is to be found in the urine of the stables. The urine and droppings of a *full grown* cow, or horse, contain a quantity of saline and mineral ingredients, exactly equal to the quantity of the same substances contained in the food consumed. In the solid excrements are found those ingredients which, as they passed through the body of the animal, resisted the action of the fluids with which they came in contact. This somewhat singular statement will appear perfectly credible when we consider that a full grown horse, or cow, consumes food for years together without increasing in weight; that is to say, the mean or average weight of a milch cow, a working horse, or ox, is the same throughout a period of many years.

Certain constituents of the food assume the form of muscle, bone, and blood, *supplying the place of an equal amount of worn-out and useless materials, which are discharged from the body in the urine.* (art. 168.)

105. In 1000 lbs. weight of the urine of the horse, there are found about 45 lbs. of soluble saline and mineral ingredients, and 31 lbs. of a substance called UREA, which, upon decomposition, resolves itself altogether into Carbonic Acid and Ammonia. In 1000 lbs. of the urine of a cow, there are found about 43 lbs. of saline and mineral ingredients, besides 18 lbs. of urea. A horse voids, on an average, 3 lbs. of urine in a day. From November to March he will void about 450 lbs., containing 14 lbs. of urea and 20 lbs. of soluble solids, as much as is contained in 200 lbs. of guano. A cow voids from 20 to 40 lbs. of urine in a day, according as she gives milk or not. If we take the lesser number, her urine will afford, during five months, 54 lbs. of urea, and 130 lbs. of soluble solids, as much as is contained in 500 lbs. of guano.

106. A drain from the stable, or cow-house, to a barrel sunk in the earth, affords a convenient mode of collecting urine, from which it may be carted, when well diluted with water, either in the liquid form, to serve as a top dressing, or *thrown at once upon the dung-heap*. Ammonia is a very volatile substance; that is, it rapidly separates itself from the decaying urine, and becomes diffused throughout the atmosphere. Gypsum, charcoal, vegetable mould, or partly burned clay, thrown into the barrel, or

upon the floor of the stable, or on the dung-heap itself, will collect and fix this very volatile and useful body.

The sheep-fold is an important contrivance for obtaining and distributing a supply of excellent manure. Sheep, however, can not be fed off the land during the winter season in this country; they may be folded in a yard, provided with a close shed and well littered with straw. By this means their droppings are preserved, and form a very useful addition to the manure heap.

107. Green Manuring.—The best mode in which vegtable manure can be applied to poor sandy soils, or clay soils scantily supplied with vegetable matter, is by ploughing in certain green crops. The juices of the vegetable rapidly ferment, and induce decomposition in the substance of the stalk and leaf itself; and being covered by the soil from the external atmosphere, all the products of decomposition are retained. Green crops, when used for enriching the soil, should be ploughed in just before the seed is formed, as at that time they are more juicy than at any other period. Buckwheat is usually employed in Canada. Clover affords an excellent artificial means of introducing vegetable matter into the soil; wheat after clover is usually of superior quality and abundant in yield.

108. Gypsum.—Gypsum (Plaster) is a very necessary article in the hands of the farmer: he may use it as a top-dressing, or strew it over the floor of the stable, or sprinkle it upon the dung-heap, or sow it with the seed. In all cases it serves two purposes:—1st, to fix the ammonia of the

atmosphere, and of vegetable substances decomposing in the soil; ten pounds of burned gypsum fixing as much ammonia as would be yielded by six hundred pounds of the urine of the horse; 2nd, to give sulphur and lime to his crops. Gypsum is especially useful on most soils, as a top-dressing for clover and the grasses. It is applied at the rate of from three to five bushels to the acre.

The mode in which it exercises its beneficial influence, probably differs according as it is used for a top-dressing, or distributed with the seed. Its effects depend very much upon the condition of the crops, when it is used as a top-dressing, and on the season, when planted with the seed, as with Indian corn or potatoes. It is most advantageously sown upon grasses and clover when the leaves are well developed, and before a shower of rain. It cannot be expected to produce much effect upon Indian corn or potatoes in a dry season, because of its great insolubility in water.

109. It has been already remarked, that the effect of Gypsum is greatly increased by mixing it with its own weight of common salt before sowing. The salt enables the plant to obtain the sulphur of the gypsum with ease and rapidity; it also affords a supply of Soda, which, as shown in art. 58, is capable of entering largely into the composition of wheat. Indeed, all vegetables seem to posses the power of assimilating Soda, when that substance is accessible; it is thus that we find crops growing near the sea, (near salt,) contain Soda in abundance, whilst those growing at a distance from any natural source of salt contain but a very insignificant quantity of Soda. Salt exercises a very favourable influence on meadow land,

especially when the meadow has recently being reclaimed from a low swampy soil. Gypsum is to be found in large quantities in the neighbourhood of Paris, in the township of Dumfries, and at many points on the Grand river.

110. LIME.—Burned Lime has been the successful agent in accelerating the restoration to fertility of numberless worn-out farms in Europe and America. It quickens the decomposition of clay, and forms with the Potash, Soda, and Flint of the clay, new compounds soluble in water. It opens and increases the porosity of stiff soils, depriving them of that tenacity and adhesiveness which is frequently an obstacle to working them, and a still more serious impediment to the expansion of the roots of young plants, and the filtration of rain-water. Lime hastens and increases the effects of manures, and improves the sample of all kinds of cultivated crops, especially those grown for the sake of their seeds. It is the great enemy of AMMONIA, expelling that substance from its union with vegetable mould and decaying farm-yard manure. The Ammonia thus set free, is absorbed by the clay, or dissolved by the water in the soil, and thus taken into the circulation of plants.

111. Many pernicious weeds are destroyed, and nutritious grasses improved, by the action of lime. It exerts a decided influence upon the duration of the growth of grain-producing crops, occasionally hastening their maturity by several days. Its effect upon soils containing a large quantity of vegetable matter is remarkable. Many acids are formed in the soil during the decomposition of roots, manures, &c.; these are often highly injurious to

cultivated crops. Lime, however, neutralizes them, and occasionally forms nutritious compounds out of the unwholesome or poisonous ingredients.

It not unfrequently happens that soils containing considerable quantities of Lime are nevertheless benefited by an artificial application. The fact is, that cultivated crops, being crops of rapid growth, derive the lime they require from Chalk, (Carbonate of Lime,) or Gypsum, (Sulphate of Lime); other forms of Lime may exist in abundance in the soil, but not applicable to plants of rapid growth, in consequence of their comparative insolubility in water.

112. The quantity of Lime to be applied to the acre is dependent upon the nature of the soil; from twenty to forty bushels are frequently required by retentive clay soils. On fields which have been under crop for many generations, as much as 150 bushels are occasionally sown. A much smaller dose is found sufficient upon the comparatively virgin soils of even the longest settled portions of Canada West. A small dose of from 25 to 40 bushels to the acre, and distributed at intervals of four or five years, is, in fact, more advantageous than 150 or 200 bushels distributed at once. When a farm has been restored by the application of Lime, care must be taken not to grow grain crops after grain crops, otherwise the soil will become barren for many years. If a farm has been injured after the application of Lime, by injudicious cropping, the only remedy is repose in grass, or the extensive use of farm-yard manure.

113. The effect of a proper application of Lime upon

the amount of produce raised is often astonishing, and distinguishable for many years. Numberless instances are recorded of a single application having increased the average from eighteen to twenty-eight bushels of wheat per acre. Virginia owes the restoration of her worn-out soil to a liberal application of burned lime. Burned lime should never be applied immediately before or after *old* farm-yard manure; and should be sown as long as possible *before* the crop. When meadows are about to be broken up for wheat, a liberal application of Lime is usually attended with great advantages. When sown on a summer-fallow, early in the year, its effects will greatly improve the succeeding crop.

114. Limestone occurs abundantly in many parts of Canada West. It is found at Malden and on the eastern shores of Lake Huron. Rocks of this formation stretch across the country from Owen's Sound to the Falls of Niagara. On the north side of Lake Simcoe, we find them cropping out at Orillia; thence through Rama and Mara, to Bellville and Kingston, Cornwall and Bytown. Limestone always contains traces of phosphorus. Its value as a manure is greatly increased when the proportion of phoshorous is large; when, for instance, it amounts to one-half, or one per cent.

115. Marl.—Marl is a mixture of Lime and Clay. It frequently contains other substances, as Potash and Magnesia; and when in the form of Shell Marl, perceptible traces of remains of the once living occupants of the broken and crushed shells. Marl can be beneficially applied to the land when in stubble or in grass, at the rate

of from ten to fifteen loads to the acre. Shell Marl is found on the shores of Cook's Bay, Lake Simcoe, and in the neighbourhood of Bytown.

116. Leached Wood Ashes.—When wood is burned, many of its mineral and saline ingredients become insoluble in water. This is especially the case with the lime, and compounds containing sulphur and phosphorus. The soluble portioh of ashes consists almost altogether of potash and soda, which are dissolved out when water is filtered through them, in the process of making black salts or ley for the soap-boiler. In treating 100 lbs. of good ashes with water, from 20 to 40 lbs. of soluble ingredients are conveyed away by the water; the remaining portion, weighing from 60 to 80 lbs., forms an excellent manure, which may be used as a top-dressing, or mixed with the dung-heap.

117. In some instances, leached wood ashes may be considered preferable to unleached wood ashes, especially on soils which do not contain much vegetable matter, without their application is accompanied with a large distribution of farm-yard manure. The Potash and Soda of the unleached ashes cause a very rapid decomposition of vegetable substances. They greatly impoverish a soil when applied too freely, their effects being more powerful than those of lime. Leached ashes, however, act slowly and beneficially for a long period of time. Many thousands of tons of leached ashes lie in neglected heaps throughout all parts of Canada West, particularly in the neighbourhood of soap manufactories, and localities where the preparation of black salts is, or has been, carried on.

## Action of Soils on Manures.

118. From the results of the experiments of Professor Way, chemist to the Royal Agricultural Society, on the properties of soils, it appears that clay and loamy soils possess most important chemical powers for the decomposition of animal, vegetable, and mineral substances, when diffused throughout their substance, as in the process of filtration or drainage. Professor Way states, that it is only necessary to stir up a quantity of clay or loamy soil in solutions of Salts of Ammonia, Potash, Lime, Soda, Magnesia, &c., in order to observe this remarkable property. The clear liquid remaining after the subsidence of the particles of clay, will be found either entirely free from the Alkali employed, or sensibly diminished in strength. The soil of an acre of land one inch in depth will weigh 100 tons, or 10 inches in depth, 1000 tons. This quantity of soil would arrest and combine with three tons of Ammonia, 10 tons of Potash, 15 tons of Sulphate of Ammonia, or 15 tons of Carbonate of Lime. In order to furnish three tons of Ammonia, 15 tons of Sulphate of Ammonia, or nearly 20 tons of Peruvian Guano, must be employed, which, at £10 a ton, would be worth £200. The Ammonia of decomposing vegetable and animal matter is thus carefully treasured up by clay soils, for the sustenance and nourishment of vegetable life.

119. These effects, so important to Agriculture, can only be produced on a large scale under a system of efficient drainage. They point out, however, in a remarkable manner, the value of the liquid manure of the

stable, and of manures generally in a liquid form. They are also leading to a more economical and judicious mode of distributing fertilizers, which must, in a few years, prove of incalculable advantage to the interests of Agriculture, although not yet applicable on a large scale in this country. The action of drains, in thus drawing out, as it were, the properties of soils, depends upon the immense increase they give to what is termed *surface action.* A soil in which all the superfluous or drainage water is conveyed away, either naturally or artificially, becomes at once remarkably porous, and receives in consequence a very large quantity of atmospheric air, as may be shown by the following simple experiment:—

Introduce a piece of dry pine charcoal into a wide-mouthed bottle; fill the bottle with cold water, and immerse it with the mouth downwards in a pan or other vessel; place on a stove or fire. Care must be taken, in immersing the bottle, that no air enters into it. As the water warms, the air contained within the pores of the charcoal will expand, and issue from them in the form of a minute and continuous stream of bubbles, which, collecting at the top of the bottle, will show the quantity contained within the pores of the charcoal. When the charcoal is taken out of the bottle after cooling, it will be found much heavier than before, having absorbed water in place of air. It is thus that soils, when well drained, contain large quantities of air, which circulate around their particles during every change of temperature. When undrained, their pores, or spaces between their particles, are filled for long periods of time with stagnant water, prejudicial to the growth of the roots of vegetables.

120. Solid, and even fluid bodies, possess the power of condensing upon their surfaces thin films of atmospheric air. The quantity of air in actual or very close contact with a solid body will depend, therefore, upon its porosity, or in other words, upon the extent of surface it exposes. A piece of window-glass will thus condense far less air upon its surface than when reduced to a fine powder and loosely laid in a heap. A sandy soil, or a porous soil of any description, may be supposed to possess the power of condensing upon the surfaces of the innumerable multitude of particles of which it is composed, films of atmospheric air. The oxygen of the air is presented to the vegetable or animal matter which may be present in the soil, or artificially introduced in the form of liquid manures, in a very condensed state, and in a measure free from that repulsion which separates its particles in the atmosphere. Under such circumstances, chemical action can scarcely fail to take place. The Oxygen will combine with the Carbon or Hydrogen of the manures, and form with them Carbonic Acid and Water. Hence, filtration through any porous substance of considerable depth entirely changes the nature of the vegetable or animal impurities filtered liquids may contain; and sewage water, the drainings of the stables or manure heap, when well diluted with water, become most powerful manures, because the ingredients they contain are immediately arrested by the soil, exposed to surface action, and made at once available food for crops.

121. In *illustration* of the important aid farmers can render to the soil by the adoption of improved methods, I append a few remarks on some experiments which have recently been made in England. They are not applicable in the present condition of Canadian Husbandry and labour, yet they involve principles which are universally interesting, and deserve, on that account, to be widely circulated. The system adopted by the celebrated Jethro Tull, who, one hundred years ago, successfully grew wheat after wheat for many succeeding years, and thus gained the name of Prosperity Tull, has recently been revived by a Mr. Smith. That gentleman has grown wheat after wheat, with excellent crops, for twelve years on the same land, and without manure.

The practice adopted by old Jethro and Mr. Smith, is now much canvassed. His plan is to divide his land into strips of about one yard in diameter, and numbered, as we will suppose, 1, 2, 3, 4, 5, 6, 7, &c. With the spade he digs Nos. 1, 3, 5, 7, &c., to the depth of 15 or 20 inches, and dibbles in the wheat in September, at the rate of two pecks to the acre. He writes this year, that with two pecks to the acre, every looker on says *it is too thick.* When the wheat appears so far above the ground that the workmen can see it, they are set to dig and trench the spaces numbered 2, 4, 6, 8, 10, &c., fifteen or twenty inches deep. They leave it rough, and it remains fallow until the crop on the sown strips is reaped. The blank rows are then sown with two pecks to the acre; the other rows are in their turn dug, and so on, each strip being thus alternately cropped. The average produce of the twelve years has been above twenty-eight bushels to the half acre, or fifty-six bushels to the acre. The land, it must be borne in mind, is thoroughly drained. It is generally thought that an occasional dressing of manure should be used, especially of those mineral manures which are adapted to restore to the soil the mineral ingredients abstracted by cropping; for, notwithstanding the rapidity with which its saline and mineral constituents are converted into available food, and the great depth to which the roots of vegetables are capable of penetrating the soil, in consequence of its remarkable porosity, it is certain that long-continued cropping must eventually exhaust the available supplies of Phosphorus and Sulphur compounds.

It is easy to see that the storehouse of organic food Mr. Smith and Jethro Tull found in the atmosphere, the stores of gaseous food (Carbonic Acid and Ammonia) there existing, are made available through the agency of falling rain, which, besides abundant supplies of food, brings down *heat* (art. 83), which it carries with it, and, as it were, deposits it in the soil existing between the surface and the drains. It will be remarked, that the rain filters rapidly through the porous soil, and *leaves behind* its supply of gaseous food for immediate assimilation, and its three per cent. of oxygen (art. 30), to assist in the solution of the requisite mineral ingredients.

A new light seems to have dawned upon the minds of men, in relation to the great and first principle of farming—DRAINING. There appears to have been a great error in this most valuable practice. The drains, hitherto, have been constructed too far apart in the heavy clays, which has led to much disappointment and discouragement. Mr. Payne, a gentleman of property and education, and who farms largely, has recently written on this subject. He originally drained at intervals of 30 to 40 feet: his land being the heaviest clay; the benefits he derived from the process were partial and unsatisfactory. He changed his plan, and drained largely at *twelve* and *fifteen* feet apart, expending £16 sterling an acre on the work; the result is most satisfactory: previously, continued failure and disappointment; now, entire success, the crops being enormous. One field on Mr. Payne's farm had an area of fourteen acres; it was drained at twelve feet apart and four feet deep, except a small corner in which the drains were put fifteen feet apart. The whole of the field was quite level, there being no surface furrows after the crop was sown. To test the effects of close draining, he had a number of holes dug two feet deep, and after ten hours continued heavy rain, Mr. Payne, accompanied by his bailiff, went to inspect the field; the soil being the heaviest clay. No water was found on the surface, but rivers were pouring from the drains. Over the whole of that part of the field where the drains were placed 12 feet apart, no water was found in the holes; but in the corner where the drains had been placed 15 feet apart, about two inches of water was found at the bottom of the holes, a result most satisfactory. The facts thus ascertained and published by Mr. Payne have elicited many letters of thanks from other farmers scattered about England and Scotland. Mr. Payne states, further, that the land in his neighbourhood, which could not be let for more than two shillings and sixpence sterling an acre, previously to draining, now readily lets for thirty shillings sterling an acre, after being improved by his close system. The real advantage we reap in Canada, by the publication of the results of extensive experiments, similar to those recently given to the world by Mr. Payne, consist in the satisfactory confirmation they afford of the fundamental principles of the Science of Agriculture; and the encouragement we derive to prosecute the study of a branch of knowledge which reveals the true character of the astonishing, yet simple relations existing between vegetables, air, and soils. It would betray great ignorance of the circumstances under which Husbandry is prosecuted in this country, to recommend the adoption of those expensive artifices which prove remunerative in Great Britain and Ireland; for not only do the circumstances of Canada, in relation to *capital* and *labour*, differ immeasurably from those which obtain in the densely peopled countries beyond the seas, but the condition and tenure of the soil, and the price of produce, forbid their introduction at present, for many obvious reasons. Our attention must first be directed to the more economical and less artifical methods (art. 75), which every man may practice, of assisting a naturally fertile soil to yield an abundant return without DETERIORATION; and if we succeed in that great problem, we shall still be relatively in the same condition as those who have had recourse to extraordinary artifices, in order to restore the fertility of soils so exhausted by centuries of cultivation, or naturally so unproductive, that the simple methods which may answer every purpose on our vigorous soils, have there failed, in numerous instances, to produce remunerative returns.

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## RECAPITULATION.

23. The object of applying Manures to the soil is two-fold:

1st. To introduce an equivalent for that supply of vegetable food which is necessarily abstracted by repeated cropping.

2nd. To ameliorate the condition of the soil, by rendering inert matter available as food; by improving its physical characteristics; and by destroying noxious compounds.

24. Farm-yard Manure is the best kind for general purposes; it contains all the elements required by vegetables, and a large proportion of them in a proper state for immediate assimilation.

25. The liquid portion of Farm-yard Manure is eminently serviceable in affording a supply of organic and inorganic food.

26. It becomes a matter of great importance, in the long-run of years, to apply to the soil the droppings of every kind of stock kept on a farm. It is advisable to form a compost heap, on which animal and vegetable refuse of every description may be thrown, and covered with a thin coating of loam, in order to arrest the gaseous products of decomposition.

27. The ploughing-in of green crops, or occasionally laying arable land down to grass, affords a speedy and

economical mode of enriching poor or exhausted soils. These artifices serve also to draw soluble mineral ingredients from the subsoil; leaving them in the surface-soil by means of decaying roots.

28. Among Mineral Manures, Lime is generally the most economical in effecting the solubility of necessary ingredients in clay or sandy soils. Its effects upon vegetable matter, when not applied in too large quantities, are highly advantageous, assisting its decomposition, and liberating available food for growing crops.

29. Leached Wood Ashes, when accessible in sufficient quantities, constitute a very useful mineral manure. They contain all the mineral elements required by plants, and operate beneficially upon the organic matter in soils.

30. Crushed Bones are especially adapted to improve old pastures; they restore to the soil the phosphates exported in the form of milk, butter, and cheese; their organic portion, upon decomposition, adds to the available nitrogen of the soil.

# Part Second.

## ON THE RELATION OF VEGETABLES TO ANIMALS.

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## LECTURE V.

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Division of Vegetable Principles—Principles containing Nitrogen—Principles not containing Nitrogen—Woody Fibre—Starch—Sugar—Isomeric Bodies—Oils and Fats—Nitrogen Principles—Relation to Animal Life—Recapitulation.

122. The results of modern investigations into the chemistry of vegetables and animals, furnish us with most striking and comprehensive views of the relationship existing between them. The products of vegetable life are capable of being converted, by the wonderful process of digestion, into bone, sinew, flesh, and blood. In other words, the gases of the air, and the mineral ingredients of the soil, assume the form and substance of sentient and moving beings, through the instrumentality of vegetables, and those vital energies with which animals are endued by

the Creator. The purposes served in the animal economy, by the compound bodies, or vegetable principles, such as woody fibre, sugar, starch, oil, &c., which are found to exist in vegetables, constitute a subject of deeply interesting enquiry, and in no other field of scientific research, have the labours of chemists been rewarded with such beautiful and surprising results.

123. Among the innumerable products of vegetable organization, not more than nine or ten are of direct interest to the Canadian farmer; and they derive importance on account of the admirable purposes they serve as food for man and animals, or as raw materials for the use of the manufacturer and artizan. They are susceptible of division into two great classes, according to the elementary substances of which they are composed; and it will be abundantly sufficient for all the purposes of practical Husbandry, to adopt this characteristic distinction, without entering into descriptive details of many substances, which, although of vast importance in other practical Arts and Sciences, do not enter into the composition of vegetables usually cultivated by our farmers, or play important parts in the nutrition of animals.

## First Class.

### Principles not Containing Nitrogen.

| | |
|---|---|
| 1. Woody Fibre,<br>2. Starch,<br>3. Gum,<br>4. Sugar,<br>5. Oils. | Composed of Oxygen, Hydrogen and Carbon. |

SECOND CLASS.

PRINCIPLES CONTAINING NITROGEN; (PROTEINE COMPOUNDS.)

| | |
|---|---|
| 1. Vegetable Albumen,<br>2. Gluten,<br>Veg. Fibrine : Veg. Caseine. | Composed of Oxygen, Hydrogen, Carbon, and Nitrogen. |

(Albumen and Fibrine both contain Sulphur and Phosphorus; Caseine contains only Sulphur.)

124. The presence or absence of Nitrogen constitutes a great and important distinction between the two classes of vegetable substances. It is found to exercise the most astonishing influence upon the purposes served by them in the animal economy, when used as food. It appears, that the nutritious parts of vegetables—those which go to form muscle, hair or wool, cartilage, and the organic part of the bones—are always distinguished by the presence of Nitrogen. Particular attention, therefore, is due to this substance, in relation to the food of animals.

125. WOODY FIBRE.—Woody Fibre forms nearly the whole mass of forest trees; and about one-half of the stalks of grasses, and straw of grain-producing crops. Its quantity in succulent roots, such as the turnip, beet, carrot, potato, &c., is very small, being rarely more than from two to four per cent. Woody Fibre is formed of carbon and the elements of water; it decomposes slowly, when exposed to moisture and air; it is then converted into two compounds, carbonic acid, and vegetable mould; when the last-named substance is exposed in a moist state to air, it absorbs

oxygen with rapidity, and gives off an equal quantity of carbonic acid. It is thus that the decay of vegetable mould affords an abundant supply of food to young plants.

126. When woody fibre is in contact with potash, soda, or magnesia its decay is much accelerated; when surrounded or impregnated with an acid substance, as strong vinegar, or weak spirit of salt, decomposition is very much retarded. The decay of woody fibre is a question of some interest to farmers and builders; great expense is occasionally incurred in renewing sleepers, sills, gate-posts, fences, &c., which have decayed immediately above the soil, where they come in contact with moisture, the potash, soda, and lime of the soil, and the oxygen of the air. If charred by burning, or coated with pitch, coal-tar, &c., the decomposition of the wood will be greatly retarded. An excellent mode of preserving wood is extensively used at present in England: it consists in placing the wood to be cured in a common boiler, which is then nearly filled with tar-oil, the air being afterwards pumped out by means of exhausting air pumps; a fresh supply of oil is then forced into the boiler by hydraulic pressure, and allowed to remain in contact with the wood for some hours. The effect produced is such as to render any kind of wood perfectly insensible to exposure, and free from the attacks of insects; iron bolts will not rust when driven into it. The expense of preparing the wood in England is from 13 to 18 shillings per load.

127. Pure woody fibre is found in the forms of the fibres of cotton, hemp, flax, &c., and thus constitutes a most important material for the manufacture of textile fabrics. Bleaching consists in the destruction of oils, resins, and other matters which are associated with the woody fibre.

and discolour it. Woody fibre may be converted into gum, sugar or starch, all of which bodies may be said to consist of carbon and water. By a process requiring a little nicety in manipulation, it enters into combination with Nitrogen, and is changed into a very explosive compound, known as gun-cotton.

Woody fibre exhibits a singular attraction for the predominate constituent of clay and alum, namely, Alumina. When cotton or linen cloth is dipped into a solution containing acetate of Alumina, (a compound of acetic acid, or the acid of common vinegar, and the earth Alumina,) the earth immediately combines with the substance of the cloth, and forms an admirable basis for fixing various colouring matters used in the process of dyeing.

128. STARCH.—This very important vegetable substance is found in the seeds and roots of all cultivated plants.

| | | |
|---|---|---|
| Wheat Flour contains from . . | 50 to 75 | per cent. |
| Barley Flour . . . . . . . . . | 65 to 70 | do. |
| Rice . . . . . . . . . . . . . . | 80 to 85 | do. |
| Indian Corn . . . . . . . . . . | 75 to 80 | do. |
| Potatoes . . . . . . . . . . . . | 13 to 15 | do. |

It is found also in the bark of many trees, especially in that of the willow and pine. By a simple process it can be obtained from shorts in large quantities; the shorts must be mixed with water, and allowed to remain in the vessel until the whole mass ferments and becomes sour, for the purpose of removing the gluten, (art. 135.) which would otherwise retard the separation of the starch. One of the first results of the germination of seeds is the conversion of their starch into sugar; which, being composed of carbon, oxygen, and hydrogen, serves as the food of the young plant, for the formation of its first roots and leaves. The process of germination is imitated in malting. The starch of the grain is converted into sugar, which, in the manufacture of beer, breaks up into two new substances, carbonic acid, rising in bubbles (froth), and alcohol.

129. Starch is completely insoluble in pure cold water; but the roots of maple, beech, &c., contain a substance named Diastase, which possesses the property of rendering starch soluble in water, (art. 136.) During the autumnal months, starch is deposited in the wood through which the sap ascends. When spring commences, water is forced up through the roots, and dissolves a portion of the diastase, this again effects the solution of the starch the water meets with it in its course, and converts it into sugar. The process is similar to that which takes place during the malting of barley. If starch be heated until it becomes brown and smokes, it will be converted into a substance entirely soluble in cold water, and known as British Gum.

130. SUGAR.—Sugar is found in the juices of many vegetables, particularly the sugar-cane, beet root, carrot, birch, maple, &c. Upwards of five hundred million pounds of manufactured cane sugar were imported into the United Kingdom during the year 1838. In the same period France and Belgium manufactured from the beet root not less than one hundred and forty-five million pounds. From the maple, in the year 1848, Canada obtained four million pounds. The quantity brought into the markets of the world of sugar obtained from different

vegetables, amounted, twelve years ago, to the enormous number of 1653 million pounds.

131. In the manufacture of beet root sugar, the first operation consists in washing the roots, which is usually done by a rotatory movement upon a grating, in a shallow trough containing water; they are next submitted to the grinding process of a rasp, consisting of a number of small saws attached to a drum, having a rapid and uniform movement; when thus reduced to pulp, the semi-liquid mass is collected in bags, and submitted to pressure; the juice is then conveyed to the boiler; before boiling it should be mixed with common slacked lime, in the ratio of 1 lb. of lime to 88 gallons of juice; after boiling for a short time, it should be again filtered through blanket stuff, and then concentrated by boiling, in the usual manner of making maple sugar; if a fine quality is required, after the second boiling has been carried on for some time, until the juice attains the consistency of thin syrup, it is to be filtered through a layer of bone-black or finely powdered charcoal, and then concentrated by boiling, until crystalization takes place.

132. A very remarkable circumstance connected with some of the substances found in vegetables, is their identity of composition. Thus we have Starch and Gum, which differ so widely in external characters, in their appearance, their taste, their odour, composed of precisely similar materials, united together in the same proportions. In 162 lbs. of Starch or Gum, there are exactly 72 lbs. of carbon, 80 lbs. of oxygen, and 10 lbs. of hydrogen, or what is the same thing, 72 lbs. of Carbon, and

90 lbs. of water, (art. 29.) In 153 lbs. of cane sugar, 72 lbs. of carbon, and 81 lbs. of water. In 34 lbs. of oil of Turpentine, or oil of Citron, two liquids differing widely in their properties, there are contained 30 lbs. of carbon, and 4 lbs. of hydrogen. Their difference in properties is due to the arrangement of the particles of which they are composed. We may suppose the mode in which this arrangement differs to be as follow:—In one body, say Starch, one unit of hydrogen may be associated with 6 of carbon and 8 of oxygen, to form one unit of Starch. In gum, we may imagine 2 units of hydrogen to be combined with 12 units of carbon and 16 of oxygen, to form one unit of gum.

133. The various properties of these bodies being dependent upon the mode in which their particles are arranged together, afford us an excellent illustration of the beautiful simplicity and admirable contrivance exhibited in all of nature's works. They are known by the name of ISOMERIC bodies, and constitute a very important and highly interesting class of vegetable principles.

134. Oils and Fats.—More or less of these substances are found in all vegetables; they consist of a solid (stearine) and a fluid (oleine) portion, which can be separated, by first subjecting the oils or fats to cold, for the purpose of hardening them, and afterwards submitting them to pressure between folds of linen. The oil is absorbed by the linen, and may be obtained pure by immersion in hot water. The solid portions of many oils and fats are identical in composition; thus, the solid ingredient of

olive oil, butter, the goose, and of man are alike ; in other words, they are ISOMERIC bodies.

There are contained in 100 lbs. of

| | | |
|---|---|---|
| White Mustard Seed, about | . . . 36 lbs. of | Oil. |
| Black Mustard Seed, ” | . . . 15 lbs. | do. |
| Sunflower, ” | . . . 15 lbs. | do. |
| Beech Nut, ” | . . . 15–17 lbs. | do. |

135. The NITROGEN PRINCIPLES found in cultivated crops, and of interest to Canadian farmers, are two in number, GLUTEN and ALBUMEN. Gluten can be ob-obtained from flour by introducing a small quantity of that substance into a muslin bag, and washing it well in cold water. After a short time, the whole of the starch of the flour will pass through the meshes of the bag, and leave the gluten behind, in the form of a soft yellowish mass. When the water in which the flour has been washed is allowed to remain stationary for a few hours, it will become clear, and at the bottom of the vessel a deposit of starch may be seen. When the clear water is heated to the boiling point, a substance similar to the white of an egg will be observed to float upon its surface, or remain suspended in the fluid. This substance is Vegetable Albumen ; Gluten and Albumen both contain sulphur, in the proportion of one part of sulphur for every twenty-five parts of nitrogen.

136. During the germination of seeds, the Albumen or Gluten they contain ferments, and becomes changed into the substance Diastase, (art. 129.) One part of diastase is sufficient to render 2000 parts of starch soluble in cold water ; it is thus that the starch contained in the seeds of

some vegetables (wheat, &c.), and in the roots of others (potato, Jerusalem artichoke, &c.), serves to nourish the young plants before they have developed leaves or roots. It is, however, in relation to animal nutrition, that vegetable Nitrogen Principles exercise the most remarkable influence. When gluten is submitted to a careful examination, two substances are found to enter into its composition, one of which is vegetable FIBRINE, similar to the muscular matter of animals, the other vegetable CASEINE, to the curd of milk. Vegetable albumen is also identical with the white of an egg.

It is thus that the muscular matter of animals, and the chief portion of their blood (dissolved muscular matter), is furnished by vegetables. A VEGETABLE WHICH DOES NOT CONTAIN ANY NITROGEN PRINCIPLES, CANNOT ASSIST IN ADDING ONE PARTICLE OF MUSCLE TO THE ANIMAL FEEDING UPON IT.

Animals do no, therefore, FORM the substances which build up their structure; it is the office of vegetables to prepare them for animal use. The animal merely *appropriates* the muscle, cartilage, and organic bony matter, which the wonderfully constructed vegetable fabricates from the crude and inert elements of the air and soil (art. 16). "Plants have the power of absorbing and assimilating the simple elements, and forming them into ternary and quarternary compounds. Animals have not the power of assimilating the simple elements; they can only appropriate them for their nourishment, when *they are ready formed* into ternary and quarternary compounds, and this office is performed for them by plants."—(Fowne.)

137. It will be hereafter shown that a daily waste takes

place in the animal body ; that worn-out and dead particles of flesh are removed in the urine. The places of these useless and rejected particles can only be supplied by the Nitrogen Principles contained in the food ; hence it follows that diet which does not contain certain Nitrogen Principles cannot serve as nutriment. An animal feeding on such diet would soon become wasted, feeble, and diseased. "A horse may be kept alive by feeding it with Potatoes, a food containing a very small quantity of Nitrogen ; but life thus supported is a gradual starvation ; the animal increases neither in size nor strength, and sinks under every exertion."—Liebig.

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RECAPITULATION.

31. Vegetable Principles may be divided into two classes, in relation to the purposes they serve, when considered as food :—

1. Non-Nitrogenized principles.
2. Nitrogenized principles.

32. The most important non-nitrogenized principles are woody fibre, sugar, starch, and gum, together with certain oils. The first four may be said to be composed of Carbon and water.

33. The principles containing Nitrogen, named in art. 123., are susceptible of assuming the form of animal

flesh, when used as food. The principles not containing Nitrogen, cannot add to the muscular strength of the body, although they may assume the form of fat.

34. The vegetable forms flesh, the animal appropriates it.

# LECTURE VI.

Composition of Crops—Nutritious Principles—Relative value of different kinds of Vegetables for the purpose of Nutrition—Rations for Working Cattle—Milch Kine—Feeding of Cattle—Conditions of Fattening—The Calf—Cheese—Butter—Recapitulation.

138. It has been remarked, that a vast variety of Principles are formed in different species of vegetables, and that those which especially interest the farmer, or such as relate to the feeding and nutrition of man and other animals, are few in number and many of them simple in composition; the most important have already been described in the last lecture; it remains now to show the extent to which each individual substance is produced in certain descriptions of vegetables, and the duties it fulfils when used as food. Subjoined is a table prepared by Professor Johnston, to illustrate the average composition and production of nutritious and other matter per acre, for each of the usually cultivated crops.

| | Bushels. | lbs. | Woody Fibre. | Sugar Starch. | Nitrogen Principles. | Oils or Fats. | Saline Ingredients. |
|---|---|---|---|---|---|---|---|
| | | | lbs. | lbs. | lbs. | lbs. | lbs. |
| Wheat, ..... | 25 | 1500 | 225 | 825 | 150 to 220 | 30 to 60 | 30 |
| Oats, ........ | 40 | 1700 | 340 | 850 | 230 | 95 | 60 |
| Barley, ..... | 35 | 1800 | 270 | 1080 | 216 | 45 | 36 |
| Indian Corn | 30 | 1800 | 270 | 900 | 216 | 90 to 170 | 27 |
| Peas, ........ | 25 | 1600 | 130 | 800 | 380 | 45 | 45 |
| Potatoes, ... | 6 tons | 13500 | 675 | 1620 | 300 | 45 | 128 |
| Turnips, .... | 20 ,, | 45000 | 1350 | 4500 | 540 | 130 | 400 |
| Carrots, .... | 25 ,, | 56000 | 1680 | 5600 | 840 | 200 | 560 |
| Mead. Hay, | 1½ ,, | 3400 | 1020 | 1360 | 240 | 70 to 170 | 220 |
| Clover Hay | 2 ,, | 4500 | 1120 | 1800 | 420 | 135 to 225 | 400 |
| Drumhead Cabbage, | 20 ,, | 45000 | . . | . . | 1500 | . . | . . |

139. It has been ascertained by the most exact experiments, that such substances as starch, gum, sugar, and oil, which do not contain Nitrogen, cannot support animal strength, or even life, for any length of time ; those principles alone which contain Nitrogen being capable of assuming the form of animal flesh and blood, when used as food. The nutritious powers of vegetables are therefore dependent upon the amount of Nitrogenized principles they contain. It is to be observed, that the term nutritious powers refers to the capability of the vegetable to supply the materials of flesh, blood, and bone for young animals, or for the daily waste which takes place in adults, and has no allusion whatever to fat, which is either provided by the oil or fat of the food, or obtained from the decomposition of starch, sugar, and woody fibre.

140. In the above table, we find that 1,500 lbs. (25 bushels) of wheat, contain from 150 to 220 lbs. of Nitrogen principles. If we take the lower calculation, we find that 100 lbs. contain 10 lbs. of Nitrogen principles. It appears, also, that 45,000 lbs. (20 tons) of turnips will contain 540 lbs. of the same important substances. 100 lbs. of turnips will contain therefore $1\frac{1}{5}$ lbs. of nutritive matter. 100 lbs. of wheat are consequently more than eight times as valuable, for the purpose of giving bone, muscle, and blood to animals, as 100 lbs. of turnips.

141. It is to be well remembered, that the form in which different kinds of food are given to animals, has very great influence upon the actual amount of benefit they derive from them. In the juices of green vegetables, for example,

a certain quantity of Nitrogen principles, and of substances capable of being converted into fat, as sugar, starch, and gum, are found in a dissolved state. When a vegetable arrives at maturity, and is made into fodder or hay, these soluble substances assume the solid form; they are deposited in the husk of the seed, or converted into woody fibre; when in this state, they are less easily acted upon by the organs of digestion. This conclusion is fully verified by experience; green fodder, when properly administered, being always found more nutritious than when given to animals in the form of hay, cut when fully ripe.

A French chemist found that 9 lbs. of green lucerne were quite equal in foddering sheep to $3\frac{8}{10}$ lbs. of the same forage made into hay; while he at the same time ascertained that 9 lbs. of green lucerne would not, on an average, yield more than $2\frac{1}{50}$ lbs. of hay. Hence it would appear that 9 lbs. of lucerne consumed in the green state, produces as much effect as 15 lbs. when made into hay. All grain crops and green crops are, for the same reason, more nutritious, both with respect to grain and straw, when cut before they arrive at maturity. It is found, indeed, that oats will yield a fodder one fourth more nutritious when cut before the seed is fully ripe, than when it has arrived at maturity. So with respect to Indian Corn stalks, clover, vetches, peas, &c. Again, green fodder of all kinds possesses certain purgative properties, which must in some measure diminish its nutritive powers.

These facts must therefore be borne in mind, in considering the following table, by Boussingault :—

*Comparative Table of the Value of different kinds of Food for Cattle, Meadow Hay being taken as a standard.*

| Name of Vegetable. | Water in 1,000 lbs. | Nitrogen in 1000 lbs. of the Article not dried. | Theoretical Value. |
|---|---|---|---|
| | | lbs. | |
| Ordinary Meadow Hay - - | 110 | 11 | 1000 |
| Ditto, fine quality - - - - | 140 | 13 | 980 |
| Red Clover Hay, 2d year - - | 101 | 15 | 750 |
| RedClover,cut in flower, gr. do. | 750 | 6 | 3110 |
| Wheat Straw - - - - - - - | 200 | 3 | 4000 |
| Oat Straw - - - - - - - | 210 | 3 | 3800 |
| Pea Straw - - - - - - - | 85 | 18 | 640 |
| Vetches cut in flower, and dried into Hay - - - | 110 | 11 | 1010 |
| Drum Cabbage - - - - - | 923 | 3 | 4110 |
| Field Beet or Mangel Wurtzel | 878 | 2 | 5480 |
| Carrots - - - - - - - - | 876 | 3 | 3820 |
| Jerusalem Artichokes - - - | 792 | $3\frac{1}{3}$ | 3482 |
| Potatoes - - - - - - - - | 659 | $3\frac{2}{3}$ | 3190 |
| White Peas (dry) - - - - | 86 | 38 | 270 |
| Oats - - - - - - - - - | 208 | 17 | 680 |
| Field Beans - - - - - - - | 79 | 51 | 230 |
| Swedes - - - - - - - - | 910 | $1\frac{7}{10}$ | 6700 |
| Linseed Cake - - - - - | 134 | 52 | 220 |

142. Example.—In 1000 lbs. of meadow hay, there are contained 11 lbs. of Nitrogen, and 110 lbs. of water. Its nutritious value as food is considered equal to 1000, which number is taken as the standard of measurement. Red clover hay, second years' growth, contains in 1000 lbs. 15 lbs. of nitrogen, and 101 lbs. of water. Its value as food is represented by 750; that is to say, 750 lbs. of red

clover hay, second years' growth, afford as much nourishment as 1000 lbs. of meadow hay. Again :—3190 lbs. of potatoes, containing 659 lbs. of water, and $3\frac{2}{3}$ of nitrogen, in 1000 lbs. of the root, are as nutritious as 1000 lbs. of meadow hay. Or if we feed an animal with 270 lbs. of peas, it will obtain as much nourishment from them, as from 3820 lbs. of carrots; or from 680 lbs. of oats, as from 3800 lbs. of oat straw; or from 1000 lbs. of meadow hay, as from 6700 lbs. of Swedish turnips.

143. Let us suppose, for the sake of illustration, that the stock of hay runs short, and that instead of giving 20 lbs. to his horse per diem, the farmer can only afford 10 lbs. The problem he has to solve is this:—What quantity of turnips, carrots, potatoes, mangel wurtzel, oats, or oat-straw will afford a substitute for 10 lbs. of hay, and keep the teams in good working condition? The table informs us that 10 lbs. of good hay are as nutritious as 67 lbs. of turnips, 38 lbs. of carrots, 31 lbs. of potatoes, 54 lbs. of field beet, $6\frac{8}{10}$ lbs. of oats, or 38 lbs. of oat-straw.

144. There are many circumstances which interfere with the practical value of this table in its present condition. It contains within itself, however, the elements of much useful information. A working horse requires more food than one that is idle; a cow giving milk more than one that is dry. Nutritious diet, packed in a comparatively small space, is essential to a working horse; otherwise he would not have time to consume his food. But a kind of diet, occupying a *very small space*, would not fill the stomach of the animal; he would consequently feel hungry, although enough had been eaten to supply all the purpo-

ses of nutrition. Boussingault says, that a horse of the ordinary size requires from 26 to 33 lbs. of solid food, and the same quantity of water, in the twenty-four hours. If fed with oil-cake, he would consume as much nutritious matter in 6½ lbs. as in 33 lbs. of hay, but his stomach would be only partly filled, and he would still feel hungry. If fed upon wheat straw, he must consume 132 lbs. to give him the requisite nourishment; a quantity too large to be eaten in a day.

145. The usual allowance for a horse, for the 24 hours, on the farm of the last named gentleman, consists of—

| | | |
|---|---|---|
| No. 1.—Hay | 22 lbs. | |
| Straw | 5½ " | |
| Oats | 7½ " | (1¾ gallon.) |

With this ration, the teams are kept in excellent condition. Each of the following rations was found beneficial. "The animals did their work well, and were kept in good condition":—

| | | |
|---|---|---|
| Hay | 11 lbs. | |
| Straw | 5½ " | |
| Oats | 7½ " | (1¾ gal.) |
| Mangel Wurtzel | 44 " | |

| | | |
|---|---|---|
| Hay | 11 lbs. | |
| Straw | 5½ " | |
| Oats | 7½ " | (1¾ gal.) |
| Carrots | 40 " | |

146. Farmers are in the habit of attributing a stimulating property to oats, as an article of food. It is true that they contain a very large quantity of Nitrogen principles, packed in a small space. They are, therefore, highly

useful where the time taken in their consumption is a matter of consequence. 12 lbs. of good hay contain as much nourishment as 1¾ gallons (7½ lbs.) of oats, but the animal requires a far longer time to consume it, its bulk being much greater.

For working-horses, a ration of hay and oats is generally considered to be the most advantageous. They may receive, however, as part of their ration, Indian Corn, both ear and stalk, and either in the green or in the dry state; when the stalk with its large leaves is properly cured, it forms a very excellent substitute for hay. Jerusalem Artichokes, Carrots, Pumpkins, and Squashes are generally greedily devoured by horses. Cutting the fodder, and giving it in a mixed state, is gradually becoming more common in this country. The advantages derived from the process are of an economical character, both as regards the quantity of the material, and the purposes it serves as food. The mastication of the grain is insured by mixing it with chaff, and the meal is completed in less time than when the whole fodder is given. The function of digestion is also more thoroughly effected when the food is introduced into the stomach in a finely divided state.

The health and condition of horses, as well as of horned cattle, are greatly influenced by the mode in which they are stabled. The stable or cow-house should be dry, airy, well ventilated, warm, and well drained. Apertures for ventilation should be made at the highest part of the building, and corresponding orifices for the admission of fresh air, a few inches above the floor. Whenever a strong odour of Ammonia is perceived in the morning, upon first entering a stable in which horses or horned cattle are confined, it is a sure sign that the ventilation is very insufficient. Under such circumstances, the functions of digestion and respiration cannot be properly performed.

117. Milch Kine.—The influence exercised by different kinds of diet upon horned cattle is almost incredible. It is perfectly useless to attempt keeping good stock, without due regard to food. In the long run of years, with attention and care, stock always pay. We frequently hear complaints to the contrary; whence, however, do they arise? From a complete misapprehension of the use of stock upon a farm. It is perfectly true, that at a distance from markets, the sale of beef and mutton, butter and cheese, do not remunerate the farmer. Let us add to these items, Manure, and see how the balance-sheet stands. A farmer who manures occasionally and sparingly, we will suppose, has 20 acres in fall wheat; he is accustomed to reap 17 bushels to the acre; by good manuring, we may reasonably expect that he will obtain 25 bushels; an increase on his whole crop of 160 bushels, due to manure alone. The value of 40 bushels will pay for labour and time expended in the operation. There remains a clear profit of 120 bushels. To beef, mutton, wool, cheese, butter, milk, he must not only add 120 bushels of wheat, but also the improved condition of his land, before he can estimate the gain or loss on a fair proportion of stock.

118. Let us remember the principle of husbandry introduced in art. 95., THAT NO FARM CAN CONTINUE TO YIELD GRAIN-PRODUCING CROPS, ON A SURFACE GREATER THAN ONE-THIRD OF ITS CULTIVATED EXTENT, FOR MANY SUCCESSIVE YEARS, WITHOUT DIMINISHING SCALES OF PRODUCE. A farmer must have a rotation of crops, in order to preserve the

fertility of his soil. He must have manure, or recourse to fallow and wheat rotation. If the above principle be once recognized, the great advantages resulting from the preservation of a constant ratio between stock and arable land, on an arable farm, will become easily apparent. The severity of the climate in Canada, the mixed system of husbandry which universally obtains in the country, and the markets, establish the value of that ratio. It is unquestionable, that a much larger amount of stock can be kept upon a farm in the United Kingdom than in this country. Experience and circumstances alone can enable the skilful farmer to determine whether the five shift, the four shift, or three shift rotation is most remunerative. The rotation he adopts will enable him to discover the amount of stock he can sustain, bearing in mind the importance of having a sufficiency of manure for his grain-producing crops.

149. Where the value of manure is so little known, that barns and stables are occasionally shifted, as the most convenient mode of getting rid of the *nuisance ;* where fields are cropped for many years, without receiving one particle of that which is wasting near them, and where, when applied, it is taken directly from the cattle-yard, without having undergone fermentation, in order to destroy the seeds of noxious weeds, it will appear utterly incomprehensible that cattle greatly assist in improving the fertility of a farm. Happily, such a wasteful and rude system of farming practice is gradually growing less frequent in Upper Canada, although it is unquestionable, that farm-yard manure is almost universally applied without proper

preparation (art. 103), and too frequently full of the seeds of weeds, with their vitality unimpaired.

150. Every thing connected with the feeding of milch kine is of importance. They should receive their food with great regularity, and be driven to water at least twice in the day. In the winter time care should be taken to free the water trough from ice, since, when the water is very cold, cattle drink as little as possible; their supply of milk is consequently reduced. Water at the temperature of that which comes from a well 25 to 30 feet in depth is the most favourable for cattle. A good milk cow will, if well fed with a mixed ration of hay or cut straw, and some roots thrown down whole before her, yield milk for 260 to 300 days, and give on an average 10 to 14 pints in a day. Cattle of all descriptions should be housed, or at least be provided with sheds, during the winter months. A cruel and most unprofitable system prevails largely in remote townships, of permitting them to be exposed to the inclemency of the weather, with an indifferent diet of straw and what they can browse during the whole winter. Their milk necessarily fails, and when spring returns they are found in such a reduced and deplorable condition, that many weeks, and even months elapse, before they regain their strength and habit.

151. In Professor Norton's Elements of Scientific Agriculture, the following admirable remarks on the necessity of giving due attention to young and growing stock occur. "Let us consider, first, the young and growing animal. What is the system too often pursued? The best hay, the best shelter, the best litter, all the grain and roots, are bestowed upon the working or the fattening

animals. The young ones have poor shelter, coarse bog hay and straw fodder, and little care of any description. In the main, they are left to shift for themselves, with poor food, and imperfect accommodations, frequently with no accomodation at all, unless the warm side of an old stack of bog hay, or bleached corn-stalks, can be so called. As they crowd under its shelter from the wind, and eat some of the hay or stalks to keep from starving, the owner congratulates himself on the saving of food that he is effecting. I would ask him to consider whether this is really the best possible practice, and think it will not be difficult to show, that every hour of this fancied gain is in reality a positive loss. It can be made evident from the following facts. The young animal is, or should be, growing rapidly; its muscles should be developing and increasing in size; its bones growing and consolidating; its whole frame enlarging from day to day, in a rapid and almost perceptible manner. This is not to be effected by such treatment as described above. The real need at this time is for remarkably strengthening and nutritious food; a food that should contain a large proportion of Nitrogen in some form, so as to increase the muscles; and of phosphates, to strengthen and enlarge the bones."

152. The conditions for fattening an animal are satisfied if it has repose, warmth, cleanliness, and regular feeding A mixed diet of dry and succulent food, such as hay and roots, in the winter months; and good clover, or excellent pasturage, during the summer. It should be borne in mind, that when a cow begins to fatten, she gradually loses her milk; therefore it is important in fattening cows to let them run dry as soon as possible.

153. THE CALF.—Few animals grow so rapidly as the calf. The average daily increase until they are weaned, is considerably over 2 lbs. They feed upon the perfection of food—upon milk, which contains in itself all the substances required to build up the animal frame.

In 100 lbs. of a good cow's milk, there are found about,

87 lbs. of water,
$\frac{3}{5}$ do. saline ingredients, (bone-earth, &c.)
$4\frac{3}{4}$ do. sugar of milk,
$3\frac{1}{6}$ do. Oil and fat, (butter)
$4\frac{1}{2}$ do. Nitrogen Principles, (curd, flesh)

When churned, the subjoined table shows the average proportion of useful dairy products yielded by good milk:

| | |
|---|---|
| Cheese . . . . . . | 8 lbs. |
| Butter . . . . . . . | 3 do. |
| Butter-milk . . . . | 12 do. |
| Whey . . . . . . . . | 77 do. |
| | 100 lbs. |

154. The curd is a Nitrogen Principle (caseine), disolved in the water of the milk. (art. 136.) Its solubility is due to the presence of soda. If an acid be introduced into the milk, it seizes upon the soda and forms a new compound. The curd is insoluble in water destitute of free soda, it therefore immediately assumes the solid state when an acid substance is poured into the milk. This operation goes on in warm weather in the following manner:—Milk contains sugar, which is converted by a new arrangement of its particles into an acid called milk acid or lactic acid. The acid forms a union with the soda. The curd deprived

of soda is no longer soluble in water, it consequently separates in a solid form. The change of milk sugar into milk acid is effected artifically by the introduction of a substance in a state of decomposition ; as rennet, or the stomach of a calf. The decomposition which is going on in the rennet communicates an impulse to the particles of the milk sugar, which re-arrange themselves under its influence, and assume the form and properties of milk acid.

155. When butter is about to be salted for home use or the market, the greatest care ought to be taken in the way of kneading and pressing, in order to free it as much as possible from the buttermilk and curd which it contains. The quality of the salt employed, is of the utmost importance. As a general rule, Mineral salt should be avoided, as it always contains some foreign matters such as Magnesia, &c., which frequently spoil or injure the contents of a cask. Strong Marine Salt is the best for the purpose. An excellent pickle is made by mixing five parts of good Marine Salt, four parts of fine Sugar, and two parts of Saltpetre, and incorporating the mixture thoroughly with the butter, in the proportion of one ounce to a pound of butter.

Many persons object to the flavour communicated to butter, by feeding milch cows with turnips, cabbage, &c. It may be useful to know that the disagreeable taste thus imparted to the products of the dairy may be removed by the following simple process. "Take Saltpetre, three ounces ; water, luke-warm, one quart ; dissolve and bottle for use. Into each ten-quart milking pail pour one wine glassful of the solution, and milk upon it ; this will be sufficient, and no more nitre need be added to the butter."—Skilling's Agriculture.

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RECAPITULATION.

35. The strength-giving power of vegetables, when consumed as food, is in a great measure due to the quantity of Nitrogen Principles they contain.

36. The fattening capabilities to the proportion of soluble principles not containing Nitrogen; and of these, chiefly to oils and fats.

37. Green fodder is more nutritious than when in the dry state, on account of its containing, in the juices of the vegetables of which it is composed, a larger supply of soluble muscular and fattening compounds.

38. The health and well-being of stock are greatly dependent upon regular feeding and warmth during the winter season.

39. The value of stock upon a farm is not to be measured by the marketable products of the dairy or slaughter-house they yield, but by those items in conjunction with the manure they afford for distribution over the arable land.

40. Good feed and warmth are absolutely necessary for the proper growth and development of young stock.

## LECTURE VII.

Function of Digestion—Function of Respiration—Animal Heat—Purposes served by Food—Opposite Functions of Plants and Animals—Production of Manure—Relative Value of Animal Manures—Recapitulation.

156. The purposes served by the constituents of food in the animal economy constitute a subject of very interesting inquiry, and of some practical value to farmers in the management of stock. A brief view of the digestive and respiratory processes will enable us to trace the changes which take place in articles of food, before they minister to the well-being of animals. The digestive organs of the horse and the ox differ in many respects: the successive steps, and the final result obtained, are the same in both instances.

The food of the horse, after havingbeen introduced into the mouth, moistened with saliva, and well masticated, is conveyed into the stomach by the meat pipe or œsophagus, where it is subjected to the dissolving influence of the gastric juice, and converted into a homogeneous pulpy mass called CHYME. The chyme passes from the stomach into the intestinal canal, into which two liquids—bile and pancreatic juice—are poured from the liver and pancreas, or sweetbread, by means of ducts terminating in the intestinal canal, about five inches from the stomach. By the action of these liquids the Chyme is resolved into two portions, named respectively the CHYLE and the RESIDUUM. The Chyle is absorbed by a number of small vessels or absorbents, which terminate in the inner coating of the

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intestines; the residuum is propelled through the intestinal canal, and finally given off as excrements. The imbibed chyle is collected in a receptacle, from which it is conveyed by a duct into the circulation. After having been thus mingled with the blood, it is taken directly to the heart in the impure form of venous blood; from the heart it is forced through a system of arteries to the lungs, where it comes in contact with the oxygen of the air, drawn into the lungs during each inspiration. A considerable portion of its Carbon and Hydrogen combining with the oxygen of air, is now given off in the form of carbonic acid and vapour of water through the mouth; what remains, constituting purified blood, goes back to the heart, to be propelled to every portion of the body, supplying nutriment where it is required.

157. In ruminating animals we find four stomachs, all connected continuously with the gullet or meat-pipe. It is in the last of these stomachs that the process of digestion is carried on. The first is called the paunch, and prepares the food for rumination by softening it. The food then passes into the second stomach, where it is rolled into pellets for the purpose of being returned to the mouth for remastication, (the cud). From the mouth it is conveyed directly into the third stomach, where it suffers a second softening process, after which it is propelled into the fourth stomach, and thence into the intestinal canal, where digestion is completed, as before described. The time which elapses before food is returned to suffer remastication in horned cattle is about 16 hours: very hard and coarse diet requires a much longer period for preparation in the paunch and second stomach.

158. In breathing, the air is taken through the wind-pipe and bronchial tubes into the lungs, which are similar in structure to a very fine sponge enclosed in a bag. The sides of vast numbers of small cells of which the lungs are composed, and which form the termination of the minute branchings of the bronchial tubes, consist chiefly of blood vessels, so that when impure or venous blood is forced from the heart to the lungs, it is diffused by means of the small blood vessels over a very large surface, (art. 120.) and at the same time exposed to the air which is contained in the lungs, the sides of the blood vessels being so thin and porous, that although they are capable of retaining liquid blood, they cannot oppose the passage of oxygen and carbonic acid. When an inspiration takes place, the lungs are filled with air, a portion of its oxygen passes through the sides of the minute blood vessels surrounding the air cells, and is absorbed by the blood ; one part of the absorbed oxygen, uniting with the carbon and hydrogen of the venous or impure blood, is given off again in the form of carbonic acid and water, the other portion is conveyed by the blood to every part of the system, combining with carbon and hydrogen in the capillaries or small tubes connecting arteries and veins, for the purpose described in the following article.

159. When oxygen combines with carbon, or with hydrogen, Heat is liberated ; it is thus that the union which takes place in the lungs and capillaries developes animal heat, and preserves a uniform temperature of the blood, under all circumstances of health.

The production and maintenance of animal heat, as far as it is understood, involves many interesting considerations with reference to food. The temperature of the blood in man is very uniform. In a state of health and repose, it is the same, about 98°, whether tested in the cold of an Arctic winter, or in the burning climate of the torrid zone. Two processes appear to combine in producing this result —respiration and perspiration. The temperature of the blood of birds varies from 104 to 107 degrees; of serpents, from 50 to 60 degrees; of fishes, from 2 to 4 degrees above that of the medium in which they live. In all cases the production of heat is connected with the absorption of oxygen and its union with the carbon and hydrogen contained in the tissues of the body and the food.

160. Heat exists in two states—free or sensible, and hidden or latent. Sensible heat is that amount of temperature which can be measured by a thermometer; latent heat is that which is intimately associated or combined with the particles of bodies in which it resides. A change in form frequently causes bodies to give out heat, or to absorb it from surrounding bodies; in the one case increasing, and in the other case decreasing the temperature of the body and surrounding air. When air is compressed into a small space, it gives out a large quantity of heat. When cannon are bored, the boring instrument frequently loses its temper by the great heat evolved. A blacksmith hammering cold iron for a few successive minutes can make it red-hot. All these facts furnish us with illustrations of the conversion of latent or hidden heat into free or sensible heat.

161. If equal quantities of cold water and sulphuric acid (oil of vitriol) be mixed together, their temperature rises suddenly above that of boiling water. When salt and snow are mixed together, the temperature of the mix-

ture falls thirty degrees below the freezing point. In the former case, heat is evolved ; in the latter, it is absorbed. THE FORMER ILLUSTRATES THE MODE IN WHICH HEAT IS LIBERATED, WHEN, DURING THE PROCESS OF RESPIRATION, THE OXYGEN OF AIR COMBINES WITH THE CARBON AND HYDROGEN OF THE BLOOD. THE LATTER EXHIBITS THE MANNER IN WHICH HEAT IS ABSORBED FROM THE BODY, WHEN ITS MOISTURE GOES OFF IN THE FORM OF INSENSIBLE PERSPIRATION. When an animal is suffering from fever, the temperature of the blood rises, because the superabundant heat evolved in the lungs and capillaries is not absorbed by the change of water into the vapour of water, as during the process of perspiration. (art. 27.)

162. It has been stated, in art. 126., that a vegetable which does not contain any Nitrogen Principles (Gluten and Albumen, &c.) cannot assist in adding one particle of muscle to the animal feeding upon it. We observe, however, that the food of animals contains a large proportion of other substances, as woody fibre, starch, gum, sugar, oils, &c. The chief office which these ingredients perform in the animal economy, is the maintenance of animal heat, they are burned in the lungs and smaller blood vessels in the same manner as fuel is consumed in a stove ; the operation in the one case is slow and constant ; in the other, energetic and variable.

163. It is evident that a large supply of Carbon and Hydrogen, the combustible materials in the tissues of the body, woody fibre, starch, oils, &c., is required by the inhabitants of a frigid climate, where the quantity of oxygen absorbed by the blood during each inspiration is probably greater than in the temperate or torrid zones.—

It is thus that we discover a beautiful connection between the character of the climate and the nature of the food consumed. The Esquimaux devour large quantities of blubber and oil, substances consisting almost altogether of Carbon and Hydrogen. The natural heat of the body is sustained by such diet. The lumber-men on the Ottawa complain of the leanness of the pork raised on the banks of the river. The fat pork of Ohio finds a profitable market for the winter consumption of men exposed to all the severities of a climate where the thermometer occasionally falls twenty degrees below zero.

164. The evolution of Heat is not confined to animals. All parts of vegetables, except the green-coloured parts, (art. 30.) absorb oxygen during the day time, which combines with their Carbon and Hydrogen, and forms Carbonic acid and other compounds. The absorption of oxygen takes place to the greatest extent in the petals (leaves of the flower), stamens, and pistils. Latent Heat is made sensible when the absorbed oxygen combines with their Carbon, as in the lungs and blood vessels of animals; the temperature of the plant necessarily rises. Experiment has shown that the interior of a flower is sometimes five and even seven degrees above the temperature of the surrounding air; some botanists give the temperature of the flowers of certain species of plants many degrees higher.

165. We may here pause to observe a great distinction between the respiration of plants and animals. VEGETABLES ABSORB CARBONIC ACID, AND DECOMPOSE IT IN THEIR LUNGS—THE LEAVES, ASSIMILATING THE CARBON AND EMITTING THE OXYGEN: ANIMALS ABSORB OXYGEN, AND COMPOSE CARBONIC ACID AND WATER IN THEIR LUNGS, GIVING

THEM OFF WITH EACH EXPIRATION. The wisdom and beauty of this arrangement will be appreciated upon an examination of the effects which would be produced upon air, were the results of animal respiration to remain unchanged. One cubic foot of carbonic acid in ten cubic feet of air renders it unfit for the support of animal life; a far less quantity is highly prejudicial and oppressive. Liebig estimates the amount of Carbon daily burned in the body of an adult man at about 14 ounces. The quantity of Carbon consumed daily by the inhabitants of Canada West (800,000) amounts at the lowest average to 200,000 lbs., producing 700,000 lbs. of carbonic acid; other breathing animals, stock, &c., consume about five times as much. Thus in one year, by respiration alone, the enormous quantity of 438,000,000 lbs. of solid Carbon is converted into carbonic acid, and given off into the air.

The materials which support that slow internal combustion which results in animal heat are derived from the Carbon and Hydrogen contained in the tissues of the body, which are replaced by the nitrogen principles of vegetables; from the fat, which is replaced by the fat of food, or by conversion of some of its elements into animal fat; lastly, from the sugar, gum, and starch of the food. Hence, a slow yet perpetual change of the tissues composing the whole animal body is going on during life; those particles which have served their purpose being burned to sustain animal heat, the Carbon and Hydrogen they contain is expired in the form of Carbonic Acid and Water by the lungs and skin, while their Nitrogen and inorganic components are eliminated by the kidneys, and finally given off in the form of Urine.

166. The annual production of carbonic acid by the inhabitants of the world is estimated at about 154,000,000 tons, formed from 42,000,000 tons of car. bon. If to this we addthat which is produced by the decay of vegetable matter, and by burning bodies, we arrive at numbers absolutely overwhelming. Vegetables feed upon this result of animal respiration; they purify the air of a noxious gas, which is to them as necessary for their growth as the oxygen they return in equal volume to the carbonic acid absorbed, is essential to the preservation and well-being of animals.

167. Boussingault instituted a series of interesting experiments relative to the consumption of water and Carbon by different animals, during the processes of perspiration and respiration. He found that a horse discharges about six times as much Carbon in the form of Carbonic Acid as a man, and a cow about five times as much. He fed a cow and a horse with a weighed quantity of food during three days, and ascertained that the horse exhaled during 24 hours, by means of pulmonary and cutaneous transpiration about 12 lbs. and 6 oz. of water; the cow during the same period and by the same processes exhaled upwards of 72 lbs. When the excrements and an equal amount of food similar to that consumed by the animals were analyzed, the result showed that about five pounds of the Carbon and half a pound of the Hydrogen of the solid food must have been given off daily from the lungs and skin.

The production of Carbonic Acid during the process of respiration may be exhibited in the following manner :— Pour rain water on newly-burned lime, and decant the clear liquid. The lime water thus formed contains dissolved lime; breathe into it through a straw or tobacco pipe; the carbonic acid of the breath combines with the lime and forms common chalk (carbonate of lime), which renders the water milk-white. Continue breathing; after a time it will become clear again. The water absorbs carbonic acid as the air from the lungs passes through it, but water absorbing a certain amount of carbonic acid acquires the power of dissolving chalk, or pure limestone; hence the clearness of the liquid. The presence of lime at the bottom of many kitchen utensils arises from the heat to which they are exposed driving off the carbonic acid from the water, which is thus rendered incapable of retaining lime in solution.

**163.** We are now enabled to trace with greater accuracy the purposes served by food in animals.

An ox, we will suppose, consumes a quantity of food equal in nutritious qualities to 40 lbs. of hay, besides a considerable quantity of water; 40 lbs. of hay are composed of—

| | | |
|---|---|---|
| Water | 4 | lbs. |
| Woody fibre | 12 | " |
| Sugar, Gum and Starch | 15¾ | " |
| Nitrogen Principles | 4 | " |
| Oil or fat | 1¼ | " |
| Saline Ingredients | 2½ | " |
| | 40 | lbs. |

A portion of the water is given off in the form of perspired matter; another portion together with undissolved substances is ejected with the excrements; the dissolved sugar, starch, and woody fibre serve to support respiration;

they are eliminated from the body in the form of carbonic acid and vapour of water, by the lungs and skin. In a state of repose, a portion of the starch, sugar, gum, or woody fibre is converted into fat. The nitrogen principles are employed to form additional muscle or flesh. The combustible portions of the worn-out particles of flesh are burned in the lungs and capillaries, their nitrogen and saline compounds are given off from the body in the urine. The oils and fat of the food serve two purposes,—1st. That of supporting respiration, and thereby the temperature of the blood; 2nd. That of assuming the form of animal fat. The saline ingredients replace the daily loss which takes place in the bones and juices of the flesh; the rejected substances being found in the urine.

The opposite functions of plants and animals have been strikingly contrasted by a modern French writer, in the following table:—

| The Vegetable. | The Animal. |
|---|---|
| Produces the Nitrogen principles. | Consumes the Nitrogen principles. |
| Produces the fatty substances. | Consumes the fatty substances. |
| Produces sugar, starch, and gum. | Consumes sugar, starch, and gum. |
| Decomposes Carbonic Acid. | Produces Carbonic Acid. |
| Decomposes Water. | Produces Water. |
| Decomposes Ammoniacal Salts. | Produces Ammoniacal Salts. |
| Disengages Oxygen. | Absorbs Oxygen. |
| Absorbs Heat and Electricity. | Disengages Heat and Electricity. |
| Is an apparatus of reduction. | Is an apparatus of Oxydation. |
| Is stationary. | Is Locomotive. |

169. It will appear, from the foregoing article, that farmyard manure contains all the substances required for the nourishment of vegetables, and many of them in such a soluble state that they are susceptible of being received without further preparation into their system, and there serving the purposes of food. In fact, the only substances actually *consumed* by fullgrown animals, and incapable of being returned to the soil, are those organic elements

which, in sustaining animal heat, are eliminated from the body in the form of Carbonic Acid and vapour of water. It is true, that in the perspiration, small quantities of Ammonia and Salts can be traced, but the amount is too insignificant to be taken into account. Every-day experience tells us, that the exporting farmer abstracts soluble saline and mineral ingredients from his farm, in the form of grain, hay, wool, butter, cheese, beaf, pork, and horse-flesh, faster than atmospheric influences can create a fresh supply by the decomposition of the soil. He at the same time conveys away the organic food, accumulated during the lapse of ages, which assists the cultivated species of vegetables to surpass in the development of their organs, kindred species growing in a wild state. It is evident, therefore, that if he do not return a part so abstracted, in the form of MANURE, and give TIME, by a Rotation of Crops, for the solubility of the remaining part required, the fertility of his soil will decrease, and diminishing scales of production will not fail to point out his error.

The due preservation and application of manure is especially required in Canada, where the severity of the climate compels the humane and thrifty farmer to house and feed his cattle during many months of the winter season. The solid and fluid excrements are therefore accumulated in one spot, requiring care for their preservation and after disposition; a precaution with reference to the fertility of pasture lands, which is not so much needed where cattle can remain in the fields night and day for eleven months in the year, as in Holland, Belgium, and some parts of England and Ireland.

170. The quantity of fresh manure produced by the

horse and cow is nearly double the quantity of solid food they consume. Thus, if a horse or cow eat 100 lbs. of hay, the weight of the fresh manure produced will be about 170 lbs. This great addition is due to the water which the animal drinks. A farmer can always estimate the number of tons of fresh manure he will have, from the quantity and kind of food consumed by his stock. When animal or vegetable manure is allowed to remain in an unsheltered spot, exposed to sunshine and rain, the greater portion of the soluble and most valuable saline ingredients are either washed out of it, or if of an organic character, pass off in the form of Carbonic acid and Ammonia. A given quantity of farm-yard manure will have lost considerably more than half its weight before it is fully rotten; but what remains behind will be far richer in mineral ingredients than the same weight of fresh manure.

The comparative values of different kinds of animal manure are here introduced in a tabular form. The table will serve to direct the attention of the farmer to those which are easily accessible, and yet too often altogether neglected or very imperfectly preserved. Good farm-yard manure is taken as the standard of comparison, and its value represented by 100:—

| | |
|---|---|
| Farm-yard manure . . . . . . . | 100 lbs. |
| Solid cow dung . . . . . . . . . | 125 |
| Solid horse dung . . . . . . . . . | 73 |
| Cow urine . . . . . . . . . . . . | 91 |
| Horse urine . . . . . . . . . . . | 16 |
| Sheep dung . . . . . . . . . . . | 36 |
| Pigeon dung . . . . . . . . . . . | 5 |
| Fresh bones . . . . . . . . . . . | 7½ |

[*Boussingault.*

From the above table we learn that 100 lbs. of good farm-yard manure may be expected to produce as much effect as 125 lbs. of cow dung, 73 lbs. of horse dung, 91 lbs. of cow urine, 16 lbs. of horse urine, &c.

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RECAPITULATION.

41. Digestion is the general process by which food is converted into blood. The digestive organs, properly so called, are the Mouth, Salivary Glands, Stomach, Intestines, Liver, Pancreas, and the Lacteal or Chyle Absorbents.

42. Respiration is the function by which the blood is submitted to the oxygen of air for the purpose of changing its properties; thus adapting it to accomplish nutrition and the production of Heat.

43. The respiratory organs are the Lungs, Windpipe, Bronchia or air-tubes, and the air-cells or vesicles.

44. Animal Heat is supposed to be produced by the combustion of the Carbon and Hydrogen of the nutrient blood in the Lungs and Capillaries.

45. The worn-out particles of the tissues, together with a portion of the starch, gum, woody fibre, sugar, and oil, or fat of the food, furnish the Carbon and Hydrogen to herbivorous animals; their tissues, and the fat or flesh of their food, to carnivorous animals; and their own fat and flesh, to starving animals.

46. The Kidneys eliminate urine from the blood, contain-

ing the nitrogen of the worn-out particles of flesh, together with their saline and mineral ingredients.

47. The functions of plants and animals are of an opposite description. The plant manufactures principles, the animal appropriates and consumes them.

# LECTURE VIII.

Parasitical Vegetables and Insects—Rust—Mildew—Smut—Potato Disease—The Hessian Fly—The Wheat Fly—The Wire Worm—The Turnip Fly—Weeds of Agriculture—Chess—Canada Thistle—Adaptation of the Climate of Western Canada to Agriculture.

## PARASITICAL VEGETABLES AND INSECTS.

**171.** Cultivated crops in Canada are liable to many diseases produced by microscopic vegetables, as well as to the depredations of various kinds of insects. Among vegetable parasites, the most prevalent and destructive are Rust, Mildew, and Smut. The Hessian-fly, Wheat-fly, Turnip-fly, and the Wire-worm are the most formidable ravagers among the insect tribes.

**172.** Rust is a fungus (a minute vegetable), of exceedingly rapid growth, and fruitful character. It is not confined to cultivated grain-producing crops. No vegetable, indeed, is altogether free from liability to its attacks, or to the destructive growth of other microscopic plants on their flowers, leaves, or stems. The general appearance of Rust on wheat is dependent upon the state of the atmosphere. During the spring, summer, autumnal, and even winter months, the air contains multitudes of the germs or seeds of small microscopic plants, which are carried about by winds, and begin to grow whenever they alight upon a suitable soil, if the temperature and moisture of the air be sufficient to call their vitality into action. The descent of every shower of rain or even snow brings down myriads of minute seeds invisible to the naked eye, which fall upon the leaves or stalks, or pass into the system of plants with the water which enters at their roots. There are many species of Rust, the most common and destructive are the orange and the red. When found to a large extent on wheat, they absorb the nourishment of the plants, and frequently destroy the most promising crops.

173. Fungi in general absorb oxygen from the atmosphere instead of Carbonic acid; they thus assimilate more to animals than vegetables. They obtain their nourishment from the substances upon which they grow, and not directly from the atmosphere or soil. They appear to germinate underneath the skin or epidermis of the vegetables in which they have found a lodgement, and as they increase in size they protrude their heads through its pores, and even burst and destroy the texture of the epidermis.

174. It has been already remarked that the *continuous flow* of the sap in vegetables is mainly due to the pressure of the atmosphere, caused by the evaporation of the water of the sap from the surfaces of the leaves and stalks. (art. 41.) If evaporation be suppressed by any external causes the sap ceases to flow, and accumulates by capillary attraction and the operation of Diffusion in the vessels of the plant. Air, it will be remembered, can only contain a certain quantity of moisture, dependent upon its temperature. (art. 14.) When there is but little difference between the warmth of the air in the day and night times, as in damp sultry weather in June, July, and August, the air remains for some hours saturated with moisture, evaporation ceases as long as the state of saturation continues, and the temperature favours the germination and growth of the

seeds of Rust and Mildew. Rust is most frequent upon rank and luxuriant crops, as might be expected from their great evaporating surface.

175. Since the prevalence of Rust is dependent upon the condition of the atmosphere and the more or less luxuriant growth of the vegetable, the attention of the farmer must be directed to two circumstances in order to lessen the effects liable to be produced by these destructive fungi. 1st. To the period of the season in which the occurrence of damp and sultry weather is to be looked for. 2nd. To the habit of the plant. If Rust strike the plant before the seed begins to form, the most disastrous effects may be produced: if after the seed has been formed, yet before it is ripe, little apprehension need be entertained for the safety of the crop. Now, experience shows that in the climate of Canada, the condition of the atmosphere as regards saturation with moisture concurrently with a high temperature, is very seldom such as to favour the germination of the seed of Rust before the last week in June; if, therefore, at that period, the wheat plant is so far advanced as to be beyond the influence of Rust upon the formation of the grain, the danger is provided for.

176. The precautions to be taken against Rust happily constitute a necessary step in good husbandry—they are DRAINING, LIMING, and the selection of early varieties of wheat; both of the mechanical operations accelerate the growth and ripening of the vegetable and increase the strength of the straw, besides reducing the evaporating surface of the leaf. There is no question that by a judicious introduction of these artifices, the destructive effects

of Rust on wheat would be very much diminished, if not in many seasons entirely prevented.

177. Mildew is occasioned by various microscopic fungi, which attack many kinds of vegetables under circumstances favourable for their production. Numerous species are known to infest grain-producing crops ; the stalks of wheat seem to be peculiarly liable to suffer from the depredations of these minute vegetables. They do not appear to require so high a temperature for their germination as the seeds of rust. In damp situations mildew may always be seen on wheat, and at a very early period of the year, whereas Rust rarely makes its appearance until very moist and sultry weather occurs. Mildew, in Canada, does not produce such disastrous consequences as in England. This result is probably due to the very rapid growth of vegetables during our hot summers. Nature herself has provided a very effectual remedy against the germination of the seeds of mildew, which are constantly floating about the atmosphere and driven to and fro by winds.

178. The stalks and leaves of many healthy plants are provided with a coating of vegetable wax, which prevents rain from wetting their surfaces. We discover this wax (bloom) on peaches, grapes, plums, the stalks of wheat, oats, rye, on the leaves of the nasturtium, &c. As long as the wax remains there is little danger of Mildew, but in moist weather, with a loaded atmosphere, or under other circumstances unfavourable to the production of a healthy plant, wax is not formed. The disappearance of the wax is almost always accompanied by the appearance of Mildew. Like the seeds of Rust, those of Mildew may either enter the system of vegetables by the roots or enter the

pores of the stem, when, in the absence of the protective covering of wax, rains or dews are enabled to wet their exterior surfaces. It will be observed, that on healthy plants the dew is found in the morning in pearly drops, either upon the surface of the leaf or round about its edges. But dew is deposited equally upon every portion of the upper surface of a leaf on cloudless nights; it cannot, however, absolutely wet the leaves of healthy plants on account of the delicate covering of vegetable wax. The small particles of moisture attract each other and form a drop. When the leaf or stalk is wetted all over, the formation of wax has not recently taken place, and the plant is then liable to be struck with Mildew. The only precautions which can be adopted in order to avoid the attacks of these fungi appear to consist in the production of a healthy plant. The remedy for Rust, liming and draining—offers the only hopeful means to the Canadian farmer.

179. SMUT.—Smut presents us with another form in which minute parasitical plants prey upon vegetables of larger growth. It is usually found to affect grains of wheat. There are two varieties of this noxious fungus. One not discoverable until the husk is opened, when it appears in the form of a black powder, having a very disagreeable and characteristic smell. The other variety shows itself on the outside of the grain. Farmers possess a remedy for both, which consists in steeping the seed in some liquid which will destroy the vegetative powers of the fungal seeds. These seeds are so minute, that a grain of smutty wheat will infect the contents of a bushel; and wheat placed in bags which have at one time held smutty wheat will certainly be infected. The best sample for

seed should always be steeped before sowing. Various liquids are selected for that purpose—stale urine, brine, and blue vitriol dissolved in water. The last is perhaps the best. Five pounds of blue vitriol (sulphate of copper) are dissolved in ten gallons of boiling water. When the solution cools, three bushels of wheat may soak in it for six hours, the light floating grains being skimmed off. The wheat should then be drained through baskets or sieves, and dried by being rolled in gypsum or lime. The same solution of blue vitriol will serve to steep twenty bushels of wheat, and effectually provide against the appearance of smut, except in peculiar situations and in seasons distinguished by an unusual fall of rain.

180. POTATO DISEASE.—The universal prevalence of this malady seems to imply the existence of a universal agent in producing it. The results of the investigations of many chemists, agriculturists, and botanists point towards one primary cause, which is to be found in the state of the atmosphere. There is still much to be learned respecting the processes of vegetable life, yet from what is already known, the potato disease appears to be occasioned by a temporary incapacity of the atmosphere when loaded with moisture, to receive the water of evaporation from the leaves. As in the case of Rust on wheat, the vessels of the potato plant are then filled with stagnant sap, which rapidly loses its vitality, and affords a suitable soil for the growth of fungi taken into its system by the water entering at the roots. Diseased potatoes, although the root may appear to be perfectly sound on the outside, have frequently when cut open exhibited a cavity filled with minute vegetable forms. The disease is greatly accelerated by small

insects which habitually feed upon vegetables, such as the far-famed Aphis Vastator, &c.

181. All root crops are subject to the same disease as the potato, and there is no reason to suppose that the malady is of recent origin. Its existence has been noticed as long as the potato has been used as an article of food. A cure, founded upon the principle of reducing the evaporating surface of the leaves, has been adopted in Germany with success. It consists in mowing off the top leaves when the plant has attained the height of seven or eight inches, and repeating the operation every five weeks, until the tubers ripen.

Two methods of arresting the progress of the disease are given in Stephen's Farmers' Guide, as having been introduced in 1849, with promise of success. "The first was suggested by Mr. David Martin, Muirhead of Liff, near Dundee, who recommends the seed potato to be cut lengthways, not across, that some of the eyes in the rose end may be in every set; that the drills be fully one yard wide, to allow of the future culture being conducted in the best manner; that, as soon as potatoes are formed, the shaws or stems should be bent down over one side of the drill, and the earth brought over the shaws on the other side, as high as until the drill is like the roof of a house with the shaws growing out of one side of it; that when the shaws are in this position the rain is not conducted to the potato, but to the bottom of the drill. The Belgian plan was suggested by a farmer, M. Tombelle Lomba, of Namur, and it consists in cutting off the stems as near the ground as possible after the flowering is over, with a sharp instrument such as a sickle, so as not to disturb in the least the potatoes in their bed, and then to cover up the incised stumps of the stems with at least half an inch thick of earth to perhaps two inches thick."

182. THE HESSIAN FLY.—(Cecidomyia Destructor.)—The Hessian fly derives its name from the manner in which it was supposed to have been introduced into this Continent. Popular opinion ascribed its introduction to the straw brought over by the Hessian troops in the year 1776. The fly appears in the fall; the female then lays her eggs, from one to eight in number, between the leaf and stalk of the wheat plant, immediately above the first joint. The worms eat into the stem, and frequently cause it to break. They winter in the torpid state, and subsist during the spring months upon the sap of the plant. They then pass into the chrysalis state, and in autumn assume the form of the fly. Some observers suppose that the eggs are laid in the fall, hatched in 4 or 6 days, and the young grubs crawling down to the foot of the leaf, subsist upon the juices of the plant until they arrive at their full size in about 35 days. They then assume the chrysalis state and thus pass the winter, taking the form of the fly in the spring. The new brood soon lay their eggs on the growing wheat, and appear in the chrysalis form in July; as such they are found by the farmers in harvest time.

183. It seems to be well established that a strong wheat plant will support, without material injury to itself, the growth of two or three worms, while a weak and sickly plant would fail under the increased tax upon its energies. It is the frequent custom where the Hessian fly prevails to grow wheat after wheat. In ploughing the stubble into the ground, and then by a second ploughing preparing it

for the seed, the chrysalis is first buried, and afterwards turned up to the surface, or sufficiently near the surface as to permit the insect to assume the fly state during the growth of the next crop of fall wheat. The females deposit their eggs upon the leaves of the young plants, which, growing upon a soil exhausted by many succeeding crops, cannot sustain the assaults of the newly-hatched worms. If a proper system of rotation of crops were introduced upon a farm where the Hessian fly prevails, the act of ploughing very early in the autumn, and allowing the land to remain in the rough state until the spring operations for green crops commenced, would bury the chrysalis for a length of time, and effectually destroy it. Burning the stubble is also found advantageous in checking the ravages of this insect: the chrysalis being lodged immediately above the first joint, is consumed by the fire passing over the field.

184. THE WHEAT FLY.—(Cecidomyia Tritici.)—A small orange-coloured fly, which lays its eggs in the ear of wheat during the last week of June or the first week of July. The eggs are hatched in six or seven days; the insect exists in the worm state for about three weeks, feeding upon the pollen and the milky substance of the grain; it then buries itself in the earth, and assumes the form of a minute chrysalis, after which it passes into that of the fly during the following summer.

The great object of the farmer in providing against the depredations of the wheat-fly, is to have his wheat so far advanced, that when the fly appears and lays its eggs, the newly-hatched worms may not be able to penetrate the husk. The means which suggest themselves for effecting so desirable a result are to favour the early maturity of the plant by liming, draining, and a careful selection of seed.

185. WIRE-WORM.—(Elator Striatus.)—The grub of a beetle, which may be seen in localities where the wire-worm abounds, on the leaves of wheat, &c. The beetle folds its legs on the approach of an enemy, and falls to the ground. The wire-worm feeds on the under-ground stems of young plants, and frequently destroys them. Buck-wheat is highly recommended as destructive to the wire-worm. A *clean* summer fallow is also instrumental in starving them out. It is very probable that the ammoniacal liquor of the gas works would be found a very useful agent in destroying these pests.

186. TURNIP-FLY.—(Haltica Nemorum.)—This insect (beetle) is one of the most formidable enemies to the turnip crop. It appears and continues during the whole of spring and summer. Danger is only to be apprehended in the early stages of the turnip's growth, before the third and fourth leaves have been developed. Every endeavour should be made to force on the young plants by means of manure. The liquid portion of stable manure is most favourable to their rapid growth. To drive away the fly, many farmers sprinkle their young turnip crops with soot; urine and the ammoniacal liquor of the gas works would be found equally efficient in preserving the plant from its depredations. The turnip-fly is seldom seen during the day time; it then occupies the under surface of the leaf. When the sun has set, the fly may be found in abundance on the upper surface. The sense of smell of this beetle is remarkably acute; it can discern the odour of the turnip,

its favourite food, at great distances. Hence the reason why the odour of ammonia, the characteristic odour of soot, urine, and the ammoniacal liquor of the gas works, is so repugnant to the delicate sense of smell possessed by this minute and destructive beetle.

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## Weeds of Agriculture.

187. Chess.—(Bromus Secalinus.)—The appearance of this common and troublesome weed is the source of more dispute than any subject which comes within the province of the agriculturist to investigate. The most erroneous impressions respecting its origin prevail among farmers throughout the whole of Canada and the neighbouring States. Popular opinion ascribes to what is termed diseased wheat, or winter-killed wheat, the property of transmutation into chess; and this opinion is promulgated and sustained in the most positive manner, upon the deceptive and erring evidence of individual observation, without the slightest reference to the botanical distinctions which mark wheat and chess.

188. Chess is a very hardy and fruitful kind of grass, called in Britian the soft brome grass. Its seeds possess the power of lying dormant in the soil for many years without losing their vitality. There are many modes of accounting for the presence of this weed among wheat and other crops. It is sown with the wheat, or its seeds, lying dormant in the soil, have their vitality called into action when the soil is ploughed up and exposed to

light, air, and warmth, or it is conveyed by floods, or carried by winds, or carted on to the soil with manure.

189. The reason why chess *surplants* wheat, and grows with luxuriance, is to be found in bad cultivation. On undrained soils, and especially on those parts where water is permitted to lodge, the wheat plant is winter-killed or thrown out; chess, being a more hardy vegetable than wheat, survives the winter, and produces a most abundant crop of seed. Good surface draining, the use of clean seed and a rotation of crops, will soon extirpate chess, and effectually remove the impression of an imaginary transmutation. We might, with as much reason, suppose that the oak was capable of changing into the pine, the pine into the birch, the beech and maple into the poplar, the grass of the prairies into the white clover. All these apparent transmutations do take place, but the reason is to be found in the death of one kind of vegetable preparing the soil for, or permitting the growth of those vegetables whose seeds are lying dormant in the soil.

190. CANADA THISTLE.—(Cnicus arvensis.)—Throughout the length and breadth of Canada this weed may be met with in the greatest abundance. During the year 1850 certainly not less than one-eighth of the wheat crop of the country was "thrust out of life" by the Canada thistle. No one travelling in the months of July and August on the shores of Lake Ontario, from Colborne to Pickering, could have failed to observe here and there a field of wheat almost free from the presence of this noxious weed, and yet surrounded by wheat fields on neighbouring farms purple with their blossoms, presenting a forcible illustration of the good effect of careful farming.

The only sure "cure" for Canada thistle is a rotation of crops, in which clover forms a prominent element: two years of a good clover lea will destroy the Canada thistle root and branch. Repeated mowing, or spudding, is also effectual in destroying this very troublesome weed; perhaps the latter operation is the safest. The stalks of the weed should be cut about one inch below the surface of the soil, and the operation repeated whenever the young leaves appear above the surface. The repeated loss of its leaves will kill the plant, destroying at the same time the whole of its *fruitful* root, which the operation of ploughing serves only to divide into numbers of sets, from which new plants arise in process of time.

191. Many other weeds call for the care and perseverance of the farmer in their destruction, such as Blood-root, wild Camomile, Thorn-apple, Shepherd's-purse, Burrs, &c. —none, however, appear to prevail so generally as Chess and the Canada thistle. Many of these weeds are of European origin, and it has been remarked by Dr. Dale Owen, the state geologist of Indiana, that when such foreigners are first naturalized they over-run the country with amazing rapidity, and are quite a nuisance. But they soon grow scarce, and after eight or ten years can hardly be met with. It is to be regretted that the same disposition to die out does not seem to belong to the foreign weeds which have been introduced into Canada. Their rapid increase and distribution over the farms of the country is a very serious evil. Nourishment, which in their absence would find its way into farming produce, feeds them into a luxuriant and fruitful habit, which at once suppresses the growth, diminishes the yield, and impairs the sample of

those vegetables for whose benefit all the artifices of husbandry are expressly practiced. The use of clean seed, the practice of clean cultivation, of draining, and of rotation of crops, can alone eradicate those hurtful vegetables, which, from past neglect, seem now to be successfully struggling to gain exclusive possession of many fertile tracts of country.

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## Adaptation of the Climate of Western Canada to Agriculture.

192. The Climate of Western Canada possesses many peculiarities due to the geographical position of the Country among the Great Lakes, which secure to it adaptations to the purposes of husbandry superior to those enjoyed by the Eastern or Western States of the neighbouring republic.

The most important points in which the climate of Western Canada differs from those of the United States which lie north of the forty-first parallel of latitude, may be briefly enumerated as follow :

1st. In mildness, as exhibited by comparatively high winter and low summer temperatures, and in the absence of great extremes of temperature.

2nd. In adaptation to the growth of certain cereals and forage crops.

3rd. In the uniformity of the distribution of rain over the agricultural months.

4th. In the humidity of the atmosphere, which, although considerably less than that of a truly maratime climate, is greater than that of localities situated at a distance from the Lakes.

5th. In comparative immunity from spring frosts and summer droughts.

6th. In a very favourable distribution of clear and cloudy days for the purposes of agriculture; and in the distribution of rain over many days.

7th. In its salubrity.

193. The points in which the climate of Western Canada differs favourably from that of Great Britain and Ireland, are—

1st. In high summer means of temperature.

2nd. In its comparative dryness.

3rd. In the serenity of the sky.

194. The difference between the mean summer and mean winter temperatures of various localities is given in the subjoined table, and is well worthy of attention for the purpose of illustrating the mildness of the climate of Western Canada, when compared with the excessive climates of the Western States:—

| Latitude. | | Difference between the Summer and Winter Means of Temperature. |
|---|---|---|
| ° | | ° |
| 43.39 | Toronto, . . . . . . . | 39.00 |
| 41.30 | Muscatine, Iowa, . . . . | 45.00 |
| 41.28 | Fort Armstrong, Illinois, . . | 49.05 |
| 43.3 | Fort Crawford, Wisconsin, . | 50.89 |
| 41.45 | Council Bluffs, Missouri Territory, . . . . . | 51.34 |
| 44.53 | Fort Snelling, Minnesota, . | 56.60 |

The characteristics of the climates of the Western States are—

1st. Intense winter cold.

2nd. Intense summer heat.

3rd. A rapid change from high to low temperatures.

5th. A comparatively cloudless sky.

6th. The distribution of rain over a very few days; and sudden, violent, and destructive in its precipitation.

7th. A great and sudden range in the degree of humidity of the atmosphere.

195. The distribution of Heat and Light over the agricultural months, in conjunction with a humid atmosphere and an equable distribution of rain, determines the adaptation of a Climate to the purposes of agriculture. A serene sky in the summer months is not only accompanied by increase of temperature during the day time, but also by a corresponding increase in the intensity of light. The vigorous and rapid growth of vegetables in Western Canada is due to the serenity of the summer sky and the uniform distribution of rain over the agricultural months. The effect, however, of too great serenity of the sky is detrimental to agriculture. In Iowa, Wisconsin, and the Western States generally, the extraordinary duration of the clearness of summer skies, and the unequal distribution of rain over the months of the year, render the cultivation of wheat, the grasses, and the root crops far more hazardous than in Western Canada. The mean annual

| | | |
|---|---|---|
| Number of clear days, on the Lakes is about | . . . | 120 |
| " " remote from the Lakes " | . . . | 210 |
| Number of cloudy days on the Lakes is about | . . | 140 |
| " " remote from theLakes " | . . | 75 |

196. The ripening of fruits is dependent upon high summer temperatures, which are necessarily the chief causes of the geographical distribution of plants over the surface of the earth. They influence to a very great extent the agriculture of any particular country. The yellow horse chetnut disappears on the Atlantic coast in latitude 36°, while it is found west of the Alleghanies in latitude 42°. So with the black walnut, which, on the Atlantic coast ceases to grow in latitude 41°, yet is found west of the Alleghanies, in the lake country, as far as latitude 41°. The Canada shore of Lake Eric abounds in magnificent specimens of this valuable tree. Numerous individuals may be met with in the woods which measure upwards of five feet in diameter.

197. In nearly every part of England and Ireland the mean annual temperature varies from two to five degrees above the mean at Toronto. The mean summer temperature is four or five degrees *lower* than at the last-mentioned place. Hence, Indian corn will rarely ripen, or melons, squashes, and pumpkins grow to any size in the open air in the British Isles, while every one knows that these vegetables attain remarkable dimensions in Western Canada, squashes having being grown in the vicinity of Toronto which have attained the enormous weight of 260 lbs. The high latitude and insular position of the islands, favouring a cloudy sky, diminish the intensity of solar light and heat, although other circumstances concur to elevate the mean annual temperature far above that of the Province. The mean summer temperature of 57.2° appears to be the minimum requisite for the successful cultivation of wheat. The mean summer temperature at Toronto is 64.51°;

but if the means of the whole Province were taken, the summer temperature would probably be found to reach 66°.

198. To the east and west of the Lakes, (especially in the latter direction,) high summer means of temperature are invariably associated with low winter means; in other words, great, and often injurious extremes of temperature occur, particularly in the Western States. The approach of spring is consequently rapid and dangerous, the liability to spring frosts being increased almost in the ratio of the suddenness of the transition. It is thus that the comparatively gradual approach of Spring in the Canadian Peninsula, is a great advantage to the husbandry of the country. High maximum means of temperature at that season of the year, with low minimum means, are treacherous, and often, indeed, ruinous to the agriculturist. Their influence on health is also very detrimental. Compare Toronto with Muscatine, Iowa, to the west of the Lakes, in these respects.

| | Toronto. | | | | Muscatine. | | | |
|---|---|---|---|---|---|---|---|---|
| | March. | | April. | | March. | | April. | |
| | Mean. ° | Min. ° | Mean. ° | Min. ° | Mean. ° | Min. ° | Mean. ° | Min. ° |
| 1845, | 35.68 | 6.6 | 42.13 | 15.5 | 40.3 | 8. | 55.1 | 16. |
| 1846, | 26.25 | 5.4 | 39.06 | 9.3 | 40.5 | 20. | 52.7 | 28. |
| 1849, | 33.24 | 15.1 | 38.74 | 15.5 | 37.3 | 10. | 44.3 | 22. |
| Mean, | 31.72 | 9. | 39.97 | 13.1 | 39.3 | 12.6 | 50.7 | 22. |

Hence, April, with a mean temperature at Muscatine of 50°·7, sufficient to force on vegetation, suffers occasional mean *minimum* temperatures of ten degrees below the freezing point; whereas the *mean* April temperature at Toronto is nearly 11° below that of Muscatine, and effectually arrests the progress of vegetation until the danger arising from killing frosts is greatly diminished.

199. The distribution of rain over the Agricultural months is remarkably uniform; the average monthly fall from April to November is about 3.2 inches. The order of the months in relation to the fall of rain, commencing with the minimum, is April, May, June, October, November, August, July, and September. The average fall in April being 2.5 inches, and in September 4 inches. February is the most snowy month, the average fall being 27 inches, while that of the year is about 57 inches. In September, the most rainy month, we discover an admirable adaptation to the growth of certain varieties of root crops, the mean maximum temperature being 89.19°, and the mean temperature 57.11°. The greatest difference which has occurred during the last ten years in the yearly rain-fall at Toronto amounts to 21 inches; at Muscatine, Iowa, it has exceeded 25 inches. The maximum difference in summer rain-fall is 11.325 inches at Toronto; at Muscatine it has been 19.8 inches.

200. The suddenness and copiousness with which rain falls in districts to the West of the Lakes is remarkable, and occasionally proves very destructive to the standing crops. The mean number of rainy and snowy days is,

| | |
|---|---|
| In the Lake Country, . . . . | 129 |
| Remote from the Lakes, . . . | 99 |
| The average for all England . . | 152 |

201. The importance of a moderately humid atmosphere, considered in relation to Agriculture, can scarcely be estimated too highly. The most interesting, and per-

haps the most advantageous form in which atmospheric humidity exhibits itself, is that of Dew. (art. 27.)

"When we cross the Mississippi, and advance into the West, every mile carries us farther from that humid south-west wind which has traversed, or started from the surface of the Gulf of Mexico—and, of course, the quantity of rain suffers diminution—we enter a region which becomes dryer and dryer, the further it is penetrated; and beyond the hundred and second meridian, as Dr. Gregg has informed me, *scarcely ever refreshed by evening and morning dews.*" "At Hudson, Ohio, thirty miles south of Lake Erie, Professer Loomis found the complement of the dew point for two years to be 8·10 deg.; while at Toronto it is about 5·25 deg.—difference 2·85 deg. in favour of Hudson (in relation to *dryness*), which is what might have been expected from their relations to the Lakes."—Drake.

202. If we suppose that only one-thirtieth of an inch of dew is formed in one night, and that that small quantity represents the average deposition during one hundred nights, we shall still have upwards of 300 tons of water precipitated on every acre of grass land by the agency of dew alone. This quantity probably falls far short of the real precipitation. "On every acre of the sandy heaths of England fall annually from 2,000 to 4,000 tons of rain, and about 500 tons of dew." (art. 27.)

203. The destruction of forests seems to have a marked effect upon swamps, springs, and running streams. In all parts of the country neglected saw mills may be seen, having been abandoned by their proprietors, owing to the "want of water." It is a constant and increasing complaint that springs and small rivers are drying up, and

consequently that the supply of water in mill creeks is year by year diminishing. This decrease may reasonably be ascribed to the destruction of forests, whereby extensive swamps are exposed to solar radiation, and that supply of moisture arrested which they were accustomed to receive during the summer months, from the condensation of the aqueous vapour of the atmosphere by the leaves of the trees overshadowing them. The frequency of extensive swamps is one acknowledged cause of the production of early spring frosts ; it is evident, that with the progress of the settlement of forest-covered tracts, spring frosts will gradually exert less influence in producing one of the most objectional features in the climate of this country. (Further information on this subject may be found in a Pamphlet, recently published by the Author, containing "A comparative View of the Climate of Western Canada, considered iu relation to its influence upon Agriculture.")

# APPENDIX.

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Ammonia, Carbon—In article 34, &c. I have not thought it advisable to advert to the mode in which Ammonia is produced in the Soil, or in what form of combination it may enter into the system of plants. By so doing, I should have greatly increased the difficulty of presenting a popular view of the Science of Agriculture to those who are supposed to be altogether unacquainted with Chemistry. It may, however, be well here to remark that Nitrogen and Carbon probably enter into vegetables in various forms of combination, susceptible however, of producing upon further decomposition Carbonic Acid and Ammonia. The views of Mülder on this subject are highly interesting and are thus explained by Dr. Fromberg:—

"In whatever way the decay of the organic substances present in the soil be conceived—the main products being humic, ulmic, and crenic acids—there will always be a large excess of hydrogen, which, being in the nascent state, has all its properties unweakened. It is, moreover, set free amidst a decaying and porous organic substance, with a limited access of air, and at a low temperature—conditions essential to effect the production of ammonia, and to prevent that of nitric acid, which latter substance is commonly found in the heat of the tropical regions. The decaying organic matter sets free carbon, hydrogen, oxygen, and a little nitrogen. The carbon, obeying its strongest tendency in this condition, forms carbonic acid, in so far as it can find oxygen enough present in the air, which is continually circulating through the porous soil. The small remainder of carbon, if a sufficiency of oxygen cannot be procured, will combine with part of the hydrogen ; and hence the quantity of carburetted hydrogen in marshy places and stagnant waters. The remainder of the hydrogen takes the nitrogen, simultaneously liberated from the plant, and also from its intimate mixture with the nitrogen in the atmospheric air ; and thus ammonia is formed. This ammonia, the extraordinary affinity of which for humic, ulmic, and crenic acids is very well known, combines immediately with part of the decaying substances, when still in a state of humus, either extracting or producing humic and ulmic acids, with which it forms humate and ulmate of ammonia, so extremely soluble in water, and fit for progressive decomposition within the cellular tissue of the plants. Now it is evident from this, that, as the said production of humic acid is going on gradually, there are only small quantities present at the same time in the soil, that which is formed being instantly taken up by the roots. There is a continual formation and absorption of it ; and thus, though the liquid is always cold and weak, and so adapted to the tender extremities of the roots, it is *constantly* present, and so a sufficient and nourishing supply is present whenever required. The beautiful connection which this theory constitutes between the production and use of ammonia and the humic acid in the soil is evident, and certainly not the least of the advantages of the theory itself. It agrees remarkably well with the great rule of nature, that there is a close relation of causation between any two products whose presence is necessary to each other. The experiment of Mülder, showing the luxuriance of plants grown in a mixture of charcoal, ashes, and ulmic acid, superior to those grown in mere charcoal and ashes, and, at the same time, the larger quantity of ammonia *produced* and assimilated by the former, apparently tends to solve two problems at once."

ROTATION OF CROPS.—The general principles upon which every separate rotation should be arranged, whatever may be the nature of the soil on which it is undertaken, after the land has been first—as a primary consideration—completely drained and brought into a state of perfect clearness, should embrace the following rules:—

1. To avoid the immediate succession of similar crops—particularly if they be of an exhausting nature—and to throw their return as far distant from each other as circumstances will admit.

2. To grow alternate crops of artificial grass and roots, if the nature of the soil permit, in each year between the grain crops.

3. On soils which admit of alternate culture, to prefer those green crops which afford the largest prospect of food for live-stock, and which allow of the horse-hoeing husbandry for cleansing the land; and,—

4. On heavy soils, or land of any kind which requires rest from cropping; never to lay it down to grass until it is clean of weeds.—[*British Husbandry.*

A few of the rotations common in some parts of England and Scotland are subjoined, with a view to exhibit the importance attached to this interesting department of farming practice.

"The following 4-course rotation is very common in England. One-fourth of the arable land is in fallow—that term, in all the rotations, implying the period when the manure is applied—one-half in corn, and one-fourth in grass :—

| | | | |
|---|---|---|---|
| First year fallow, | 125 acres, | Potatoes, . . . . | 10 acres. |
| | | Tares, . . . . . | 10 ... |
| | | Turnips, . . . . | 50 ... |
| | | Beans, . . . . . | 30 ... |
| | | Bare fallow, . . . | 25 ... |
| Second year wheat and barley, | 125 .... | Winter wheat, . | 75 ... |
| | | Spring wheat, . | 20 ... |
| | | Barley, . . . . . | 30 ... |
| Third year grass, | 125 .... | Hay, . . . . . . | 25 ... |
| | | Clover, . . . . . | 20 ... |
| | | Pasture, . . . . | 80 ... |
| Fourth year wheat and oats, | 125 .... | Wheat, . . . . . | 95 ... |
| | | Feed oats, . . . . | 30 ... |
| | 500 | | 500 |

Wheat is a common crop after clover in England, rare in Scotland. The beans are manured in drills. The potatoes are manured, as also the tares. The turnips are well manured. One-fourth of the land requiring manure every year, and half of it under corn, the farm cannot provide the manure required, so some must be purchased."

"A 5-course rotation is very general at a distance from towns. It puts one-fifth of the land in fallow ; two-fifths under grain ; and two-fifths in grass, one and two years old. This is, however, just the 4-course rotation immediately above, with the grass member extended to two years :—

| | | | |
|---|---|---|---|
| First year, fallow, | 100 acres. | Potatoes, . . . | 10 acres. |
| | | Tares, . . . . | 10 ... |
| | | Turnips, . . . | 80 ... |
| Second year, wheat and barley, | 100 ... | Winter wheat, . | 20 ... |
| | | Spring wheat, . | 30 ... |
| | | Barley, . . . . | 50 ... |
| Third year, grass, | 100 ... | Hay, . . . . | 20 ... |
| | | Clover, . . . . | 15 ... |
| | | Pasture, . . . | 65 ... |
| Fourth year, grass, | 100 ... | Pasture, . . . | 100 ... |
| Fifth year, oats, | 100 ... | Potato oats, . . | 60 ... |
| | | Common oats, . | 40 ... |
| | 500 | | 500 |

The potatoes, tares, and turnips are all manured, which it is now quite possible to be done by the assistance of bone-dust and guano to the turnip crop. There is no necessity for a bare fallow, the soil being better occupied with a green crop. When the land is somewhat strong, a few beans with manure may be substituted for a like extent of turnips. The hay might be confined to the wants of the farm, and the cutting clover extended in the same proportion, or it might be thrown into the pasture of the first year. Some of the lea on the last year might be rag-fallowed, and wheat taken instead of oats. The 5–course rotation is a profitable one at a distance from towns. It might be modified into a 6–course rotation by extending the second years' pasture into the third year. This last course is a good one for the mixed husbandry, as it affords plenty of pasture for the young stock, and the oats yield very abundantly after a three years' lea."—[Stephens's Farmers Guide.

# INDEX.

(*The numbers refer to the articles, not to the pages.*)

# ERRATA.

Page 2, Line 6, for enables, read enable.
Page 16, Line 12, for rivers. read rivers,.
Page 25, Line 5, for varies, read vary.
Page 83, Line 20, for Bellville, read Belleville.
Page 83, Line 23, for phoshorous, read phosphorus.
Page 91, Line 5, for advantage, read advantages.
Page 99, Line 8, for predominate, read predominant.