CHYMISTRY

APPLIED TO

AGRICULTURE.

By JOHN ANTONY CHAPTAL,

COUNT OF CHANTELOUP, PEER OF FRANCE, MEMBER OF THE INSTITUTE, &c.

TRANSLATED FROM THE SECOND FRENCH EDITION.

Omnium rerum, ex quibus aliquid acquiritur, nihil est agriculturâ melius, nihil uberius, nihil dulcius, nihil libero homine dignius.—Cicero.

Good husbands will find the means, by good husbandry, to improve their lands; but it will not be amiss that they be put in mind thereof, and encouraged in their industries.—Lord Bacon.

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ADVERTISEMENT.

In offering to the public the following treatise the publishers believe that they shall render an acceptable service to the agricultural interest, the most important interest, of the United States.

The author, one of the most eminent chymists of the age, was at the same time a practical agriculturist, owning large estates, which were for a long time cultivated under his personal direction. "In order," says he, "to make a useful application of the sciences to agriculture, it must be profoundly studied, not only in the closet, but abroad in the fields." By pursuing this method he was able to describe processes, and set down the course and the results of his large experience, with a fulness and clearness, that make them immediately available to the practical farmer. "In my explanations," he remarks, "I may sometimes have fallen into error, but I do not believe that I have misstated a single fact."

The only work of note in the English language on the subject of Agricultural Chymistry is that of Davy, which was published in the year 1813. It consists of eight lectures delivered annually for ten years before the Board of Agriculture. In his preface he observes, that the rapid advance of chymical science obliged him to vary them each year they were delivered, and to alter them still further when preparing them for the press.

Ten years afterwards, in 1823, appeared the first edition of the present work, in which the author says, "The celebrated Davy has already published an Agricultural

Chymistry, and I have derived from it important principles. Others will do better than we have done." But no one came forward to verify this prediction, and, in 1829, Chaptal published a second edition, increased by several new chapters and a copious Index. To this, the author's last edition, the present translation is conformed.*

Although the work was more especially intended for France, the larger portion of it is applicable to all countries; and those chapters, which at first view seem to have only a local interest, abound in hints which may anywhere be turned to account.

And not only is the husbandman taught how to produce, but the housekeeper also how to preserve, and enjoy in perfection, the various products of agricultural labor.

The opinions of Chaptal on political science were in harmony with the institutions of the United States. He was an advocate for breaking up the large domains of France into small farms, which should gradually be purchased by those who succeeded in cultivating them. He sought to raise the peasantry of his country from their ignorance and degradation to the condition of "independent farmers," in the American sense of the term; to make them feel the intrinsic dignity of their employment while practising the most important of all arts, that which lies at the very foundation of civil society. To this end he wrote the present work, which sheds all the light of modern science upon the humblest details of rural labor; and, while it increases the productive skill of those who are engaged in practical husbandry, at the same time "advances them in the dignity of thinking beings."

* Chaptal died on the 29th of July, 1833, in his 76th year.

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INTRODUCTION.

WITHOUT agriculture, men would live wandering and unsettled lives, disputing with each other for the possession of such animals as they could make their prey, and for the spontaneous fruits of the earth. They would have no bond of society, nor country.

By multiplying the resources for food, agriculture has permitted men to unite themselves into communities for mutual assistance. Whilst some cultivate the land, to increase its productions, others apply themselves assiduously to furnishing society with the necessary implements of industry. It is thus that, by reciprocal intercourse and exchanges, commerce has been established, and civilization extended.

If living in cities, and leading the sedentary life required by the practice of many of the arts, have softened and enervated a portion of the human species, agriculture has preserved the inhabitants of the country in a state of health, strength, and good morals. Nor is it one of the least blessings which it bestows upon society, that it thus continually repairs that portion of it which would otherwise become degenerate.

Amongst all nations, agriculture is the purest source of public prosperity. Situated under different climates, their productions and modes of cultivation are extremely diversified. But commerce scatters the productions of the various soils; and thus each nation is able to enjoy the fruits peculiar to the several portions of the earth. These exchanges have connected nations together, by rendering them dependent on each other; and the advantages arising from intelligence and industry have been made to spread through all.

The agriculturist, then, holds the first rank amongst men. By what fatality has his condition, in France, been always miserably servile and degraded? Those, even, whom he has toiled to support in luxury and idleness, have often compelled him to envy the condition of the animals which assist him in his labors. The statute work, the tithes, and the other exactions of feudal power, have left him, for his subsistence, only the most wretched productions of his fields. He has watered the land with the sweat of his brow, but the fruits which it brought forth were for the enjoyment of others. In this state of misery and oppression, the cultivator of the soil followed blindly the track which was marked out for him. Without emulation, without knowledge, and nearly without interest, the thought of improvement scarcely presented itself to his mind.

It was not till the moment, when, by a wise return to the true principles of justice, the right of property was respected and received protection,—when taxes were proportionably levied, and privileges abolished,—that the farmer recognised his strength, and felt himself rising into the true importance and dignity of his state. Then, intelligence was extended to the business of the fields; the means of ameliorating the soil, and improving its productions, were established and increased; and private interest was for ever united to the public good. At that period, agriculture took a new impulse; and since then, its progress has been rapid. The nature of soils has been better known; the cultivation of artificial meadows has been extended; and a rotation of crops has been established upon principles recognised in all those countries, where agriculture has made the most progress. The number of domestic animals has also progressively increased, and, with them, the manures and the labors which form the basis of agricultural prosperity.

It remains to us, at this day, to improve agriculture by the application of physical science. All the phenomena which it presents, are the consequences necessarily resulting from those eternal laws by which matter is governed; and all the operations which the agriculturist performs, serve only to develope or modify these laws. It is, then, to the acquisition of a knowledge of these laws, in order to calculate their effects and modify their action, that we ought to direct all our researches.

Can any study present to the agriculturist more attractions, than that, which has for its object the explanation of those effects, which every day captivate his senses and astonish his reason? Without doubt, observation has made him acquainted with the uniform march of nature. In all her operations, he can judge of the modifications effected in her productions by the state of the atmosphere, the variation of climate, and the nature of the soil. Even this practical knowledge enables him to direct many of the labors of the field.

But, if he be permitted to ascend from the effects to their causes; if we can determine, and demonstrate to him, the action which is exercised upon vegetation by the air, water, heat, and light, the sun, various kinds of manure, &c. &c., and assign to each of these agents the part which it performs in these grand phenomena, how much will he be moved! Even whilst an ignorant witness of these wonders, he is lost in admiration of them: but, more enlightened, he will feel this sentiment constantly increasing, as he rises to the causes which produce them.

Convinced that we must look, for farther improvements in agriculture, to the application of the physical sciences, I think it proper here to establish some general principles, the more complete developement of which will be found in this work.

The laws of nature are eternal and unchangeable. The natural state of bodies, their respective situations, the changes which they undergo, the phenomena of decomposition and of composition, which animate the whole surface of the globe, are the results of these laws.

We see, everywhere, that matter is governed by two general laws; by the power of which all bodies exist in their natural state. The first is exercised upon masses of matter; the second, upon those molecules of which masses are composed. The one is the general law of attraction, or gravitation; the other, the law of affinity, or chymical attraction.

The law of affinity (the only one of which I shall now speak) tends constantly to draw together the particles of which bodies are composed. If this force acted alone, the degrees of density exhibited by bodies in their natural state would depend entirely upon the degrees of affinity existing between their component particles. But its action is balanced and modified by that of the fluid of heat, which enters, in various proportions, into all substances, and which tends to separate, one from another, the elements which affinity draws together. Affinity, alone, would form only solid masses, inactive, and more or less compact. The action of heat, alone, would produce only gases, or aërial substances. But the combined action of these agents presents to us bodies either in a solid, liquid, or fluid state, according to the degree of intensity with which one or the other force acts upon the component parts. The natural state of bodies, then, is owing to the combined action of the law of affinity, which brings their particles into union, and the interposing fluid of heat, which separates them from each other.

The variations which the atmosphere undergoes during the different seasons of the year are sufficient to produce changes of consistency in some bodies. Water, for instance, is either solid, liquid, or aëriform, according to the temperature of the air.

Man, who governs the power of heat at his pleasure, can produce all these remarkable changes in the natural state of bodies. He can augment or diminish their consistency at his will, and cause them to assume either the solid, liquid, or gaseous form, according as he adds or takes away that fluid.

The changes produced by the addition or subtraction of heat are not permanent. The body returns to its natural state, the moment the cause has ceased to operate,—imparting to the surrounding substances the excess of fluid it has imbibed, or receiving from them that of which it has been deprived. These alterations of form and consistency do not affect the nature of bodies; but, by bringing into contact or separating the molecules of which they are composed, they augment or diminish their cohesion and their affinity, and thus dispose them to form new combinations.

The principles which I have just explained are not rigorously applicable to animal and vegetable substances, nor to some other compound bodies, except so far as the effects of a low degree of heat are concerned. The constituent principles of such bodies do not all require the same degree of heat to cause them to pass to the liquid or gaseous state. It follows, then, that some of them can take the one or the other of these forms, by any degree of heat above that of the atmosphere, and thus be separated from those which remain fixed. In this case decomposition is produced.

If the force of affinity were the same amongst all the elementary particles of which various bodies are composed, there would be only confused aggregations of matter, throughout all the operations of nature and art. But each element has its peculiar affinities, which enable it to enter, more or less closely, into combination with certain other elements, whilst it strongly resists a union with those for which it has no affinity. All matter is formed, governed, and separated, according to these different affinities. The uniform reproduction of the combinations of art and the productions of nature is derived from this principle.

It follows from the preceding statement, that the force of affinity alone can hold in lasting combination the particles of matter,—and that bodies are, even then, liable to decomposition; for, according to the laws of elective affinity, one constituent of a compound body will forsake another, for which it has a certain degree of affinity, to unite itself with a third, for which its affinity is stronger. We thus see how important it is, for those who wish to study the operations of art and nature, to be acquainted with the degrees of affinity that exist amongst the various elementary bodies which enter into combination. Whilst the chymist influences, according to his will, nearly all the agents which are employed by nature, she can follow him in her labors, even when she cannot imitate him in her productions. She knows the materials which the chymist employs, and can often furnish them to him, and facilitate his operations. She can foresee his mistakes, and cautiously turn aside the causes which would produce them. In a word, the mutual action exercised by bodies is constantly regulated by the immutable laws of nature. But the chymist can at pleasure dispose of these same bodies of which he knows the respective affinities. He can combine them in all their proportions, submit them to all degrees of heat, and subject them to the action of external agents, the energy of which he can increase or diminish to almost any extent, and thus produce results which nature, in her constant and undeviating march, cannot give rise to. It is by means of this power, that chymistry forms, every day, new compositions, and that she has enriched industry and economy with a vast variety of productions, which, without the assistance of this science, would have been for ever unknown.

Rude and inorganic matter obeys no other laws than those of which I have spoken. All the changes which it experiences, all the phenomena which it presents, all the combinations and decompositions which take place in it, result from them. Chymistry can foresee and explain the consequences of their action. She can even produce, by her exertions, new combinations.

In addition to the laws of affinity, which govern inorganic matter, living bodies are subject to other laws, which continually modify the action of the first. These laws of vitality are energetic, and govern the law of affinity in proportion to the perfect organization of the body. It is this, which causes the mode of action in living bodies to escape our researches; so that, although witnesses of all which passes in these bodies, we can neither explain nor imitate their productions. The science of chymistry is limited to a knowledge of the substances which enter into animals and vegetables, to serve them for nourishment; and to the study of all the agents which aid them in the performance of their functions. She knows what these bodies appropriate to their use, and what they reject. But the mode of elaboration by their organs, the formation of their products, and the manner of their growth, is, and must for a long time be, a mystery to us. That which we already know of the functions of living bodies, is much; but that of which we are ignorant, far exceeds it.

The laws of vitality, like all the other laws of nature, are unchangeable. But their action is varied in living bodies by a difference in organization; in the same manner as the products vary in each species, and in each one of their organs. It is this variety of productions which surprises us,—especially when we consider, that their form and their quality are constantly renewed every year, and with every generation.

These laws of organization have, then, set the bounds, over which science has not yet been able to pass. She has, however, opened to our view some sublime pages of the book of nature; and she has made many and useful applications of their contents.

The living plant, fixed by its root to an immovable soil, has no power of motion to enable it to seek its support from distant substances. It derives all its nourishment from the earth and air by which it is surrounded. These aliments are elaborated in the organs of the plant. They are there decomposed and combined with its elements, in a regular and uniform manner. With the dead plant, the case is widely different. Upon that, other bodies exercise an action entirely physical. When organization ceases to modify their effects, the same agents, such as air, water, and heat, which assisted it in performing its functions whilst living, concur powerfully in decomposing it when deprived of vitality; and complete disorganization can only be prevented by secluding it entirely from the contact and action of these bodies.

It is at this period, that chymistry can exercise its power with full effect. She knows the elements that enter into the composition of the dead plant; she knows the various degrees of affinity by which they are united, and can predict with certainty the changes which will follow from the action of those external agents, which she can modify at her will.

From the observation of these circumstances, it is my opinion, that the knowledge of chymistry can, with advantage, be applied to the labors of the agriculturist. I believe, that, by a better acquaintance with the bodies subject to his management, by uniting well-established facts to a sound theory, by determining with care the effects of all those bodies which can exert any influence upon vegetation, and the modes of their action, we shall be able to deduce principles, the application of which will greatly accelerate the progress of the most important of our arts.

All the sciences have a natural course from which they never deviate: they begin by collecting and proving facts; and when these facts are well established, they compare them with each other, and deduce from them principles of general application.

The facts in agriculture are already numerous; but have the modifications wrought by the nature of the soil, the action of manures, the state of the atmosphere, the influence of climate, and the varieties of exposure, been sufficiently attended to? Will a fact observed in one place be constantly reproduced in another? Since such is not the case, we must necessarily come to the conclusion, that solitary facts are not sufficient to establish principles in agriculture. It is necessary that they should have been observed and verified, under the influence of all the agents of which I have spoken; and that we should know the modifications which each one produces, in order to be able to draw from them general and practical consequences. If the agents of vegetation were constantly the same, if their effects were everywhere the same, one fact alone would be sufficient to establish a principle, applicable to all localities; but the difference of their action under different circumstances necessarily produces important changes in their results: and this it is, that causes the kind of agriculture which prospers in one country, to be unsuccessful in another; and an agriculturist, who wishes to try methods of cultivation which have succeeded elsewhere, often finds himself deceived in his expectations, because he cannot unite the same circumstances to ensure success.

I have thought that a work upon the principles of agriculture, which should make known the properties and actions of the several agents which influence the results of its operations, would be really useful; and accordingly I have applied myself to forming an acquaintance with the most usual methods of cultivation, in order that I might extend the application of them to other cases to which they might be suited.

But it is not sufficient to enlighten the agriculturist, in order to facilitate the progress of the art; the government has an important duty to perform towards it. It is only when intelligence and encouragement are united, that the farmer can be assured of lasting prosperity.

Agriculture is the most fruitful source of the riches of a country, and of the welfare of its inhabitants; and it is only as the state of agriculture is more or less flourishing, that we can judge unerringly of the happiness of a nation, or of the wisdom of its government. The prosperity which a country derives from the industry and skill of its artisans, may be but a passing gleam; that alone is durable, which has its rise in a good cultivation of the soil. These facts ought to be constantly present to the mind of the government, and to influence all its measures.

A government awake to its true interests will seek to facilitate and increase the cultivation of the soil, and to open new channels for the disposal of its products. It will protect property, by causing its rights to be respected, and punishing breaches of the laws concerning it; and it will guarantee the proprietor against arbitrary exactions. The taxes should be regulated in such a manner as to take from the agriculturist only a portion of the increase arising from his labors; for, if he have no surplus over his immediate wants, there will remain to him neither the means of improving his modes of cultivation, nor of supporting his family with comfort; neither will it be possible for him to renew his stock of domestic animals, nor to augment their number. Any government which does not leave to the farmer a great part of the profits proceeding from his harvests, soon puts a stop to the production of them, and thus realizes the fable of the goose with golden eggs.

By encouraging improvements in agriculture, and favoring the increase of production, government enriches the agriculturist less than its own revenues; since by these means the quantity of taxable matter is increased, and the right of government recognised under all its forms, whether the article produced be employed in its crude state for domestic use, or whether it furnish the workshop of the artisan with the materials of his handicraft.

Though the territorial imposts have been much diminished within a few years, they are still far too high for the prosperity of agriculture. A bad harvest, a mortality amongst the animals upon a domain, or a prevailing epidemic, exhausts the scanty store which the economy of the farmer had enabled him to reserve from a favorable season; and thus the greater part of them are forced to contract debts. A succession of abundant harvests hardly enables them to repair the loss sustained from the calamities of a year. The peasant, everywhere, lives only from day to day, because he has no capital, and his poverty does not permit him either to provide against or repair a misfortune.

The government of this country has been often occupied with the project of clearing those wild lands of which a part of it consists ; it has even made some attempts, and been at some expense, to carry these plans into execution. It would have been wiser to excite and encourage the improvement of those lands already under cultivation ; and by this course the best results would infallibly have been obtained. These enterprises, in a country where the cultivation of good land has not arrived at perfection, belong to the province of individual speculation, which never fails to execute them, provided it sees any chance of success.

Agriculture has for a long time required a law, which should specially encourage improvements, and effect the clearing of uncultivated grounds ; this law should fix for the future, in a permanent and invariable manner, the taxes on land brought into cultivation, so that they never should be raised on account of their produce or the value which has been bestowed on them by labor and industry. The fear alone, that taxation will sooner or later be extended to improvements, is sufficient to turn the current of capital from that all-important employment, and to throw it upon those operations and speculations which, for the most part, employ property in ways that are of no advantage, either to the nation or to the government.

Another law not less required by the interests of agriculture and society, is one having for its object the encouragement of planting forests, and the preservation of those which now exist; without some law to this effect, a future and not distant period threatens their entire destruction. Without doubt private interest, more active perhaps in our day, the division of property, and the loss of great territorial fortunes, have prepared the way for and brought on these consequences ; but the law has contributed more than anything else to produce them. In fact a proprietor pays every year a tax levied upon the trees of his domain, and it is easy for him to calculate, that it is more advantageous for him to fell those of twenty years' growth, than to leave them to attain the age of one or two centuries.

A good law regarding district roads would be a great benefit to the inhabitants of the country ; easy transportation by means of convenient roads is constantly repaying to the farmer the expense which he must be at in making and preserving them ; since they will enable his cattle to perform the same quantity of labor at a much less expense of time and strength. But it is difficult to obtain from the administration these important local improvements. The mayors, their assistants, and the members of the municipal councils, are generally the richest proprietors of a district ; and they never condemn themselves, either to restore to the public ways the encroachments they have permitted to be made upon them, or to furrow their fields by roads, or to support nearly the whole expense which these labors for the public good would require. There should be attached by law to each department, a pupil of the School of Bridges and Highways, who, a stranger to any particular local interest, should lay out district roads, determine their width, compel each proprietor to confine his boundaries within their original limits, prepare plans and schemes, and prescribe the suitable materials to be employed in the execution of them. The labors of this engineer should be subject to the inspection of the engineer of the *arrondissement*, and to the approbation of the chief engineer; upon the report of this last, the prefect should order the proposed plans to be carried into execution. The *communes* should then provide for defraying the necessary expenses, in such a manner as might be least burdensome, and present the result of their deliberations to the prefect for his approval.

Canals and highways are for society at large what by-roads are for the separate portions of it. These grand means of communication may be called the arteries of the social body, conveying life through all its parts. One of our most profound writers has said, that "rivers and navigable streams are roads which travel;" but canals present great advantages over navigable rivers; they go to seek the productions of a country in the places of their origin; their direction is always governed by the necessity of such means of intercourse; their navigation is easy, regular, and safe; they animate and give life to all the country through which they pass, without ever counterbalancing these advantages by the ravages of an inundation.

By diminishing the expense of transportation, by opening communications with the distant portions of a country, by facilitating the exchange of articles, and rendering common to a whole nation the production of each locality, all the sources of public wealth and prosperity are multiplied. By an increased intercourse between men civilization is perfected; intelligence and urbanity of manners find their way into the most secluded spots; and the law which has established a great system of inland navigation in France, will excite the gratitude of all future ages.

If agriculture requires some new laws favorable to her interests, she also demands the suppression of a small number which are opposed to them. The law should protect and favor exchanges; and government ought to view in this operation only the mutual accommodation arising to the proprietors of the property exchanged, and not to collect any duties excepting from the profits on what is exchanged. By facilitating and encouraging exchanges government would do much for agriculture; scattered and disjointed property would insensibly become collected around the dwelling of the owner; the inspection of it would thus be rendered easy, and a better system of management might be adopted without difficulty; transportation would be facilitated and rendered less expensive; the laboring animals would suffer less from fatigue, and their quantity of work be increased in value.

Another advantage arising from the exchange of property is that of annexing to some estates small portions of land lying contiguous to them, which, from their limited extent, do not give scope to the exercise of all the resources of good husbandry. These exchanges would likewise have the good effect of extinguishing a thousand disputes, which are constantly arising amongst the proprietors of real estate, about limits, usurpations, and encroachments.

But the greatest benefit which government can confer on agriculture, is without doubt the suppression of the duty upon salt. During those years in which the sale of salt was free from duty, the borders of the Mediterranean were covered with salt-works; immense capitals were employed in forming these establishments, and they sold salt to the amount of twenty millions of francs per year. The tax has given a death-blow to this beautiful scene of industry; nearly all the salt-works are abandoned. The consumption of salt has been so much reduced, that the price of fifty kilogrammes (1 cwt.) is not above twenty-five centimes in the salt-pits; and the duty upon as much salt as is sold for one million five hundred francs, produces to the treasury from forty-five to sixty millions.

In order to realize all the evil which results to agriculture from the duty upon salt, it is sufficient to know the extensive advantage arising from its employment.

Salt is of the utmost importance to all ruminating animals, increasing their relish for their insipid food, exciting the action of their membranous and weak stomachs, and preventing those obstructions of the intestines which are produced by the use of dry forage during the winter. It is generally observed that those animals are preferred in the market, which have been habitually fed upon saline plants, and that their flesh is of a superior quality. There is no farmer, who has not been able to see the difference, at the close of a winter, between those animals which have received their supply of salt and those that have been deprived of it; the first are well shaped, large, and fat; their hair is glossy, their eyes lively, and their motions prompt and firm: the second present images of suffering and misery; the sheep have lost nearly all their fleece before shearing time, and that which remains is falling from them in locks; the neat cattle are lean and sickly, their organs of digestion are impeded in their action, and it is only after having browsed the juicy herbage of spring that they recover their health.

During the time that salt was freed from any impost, the use of it in agriculture became each year more extensive; it was mixed with manures, to increase their activity; it was spread at the roots of trees, to reanimate their languishing powers of vegetation; and the quantity of salted provisions, both for market and for home consumption, was much increased.

The impost upon salt is to agriculture a real calamity, since it has taken from it many of its sources of prosperity; and at the same time the public treasury has received no advantage from the tax, equal to the injury which it has inflicted upon agriculture.

I know that in a well-organized state, the receipts ought to cover the expenditures; and that it is not possible to repeal a tax of forty-five millions of francs, without replacing it by another equally productive; but, in selecting objects for taxation, those ought to be taken which will fall least heavily on the interests of those who pay them; and it must be prudent to avoid those which will lessen production, and check improvements in industry, commerce, and agriculture. In establishing a tax it is likewise necessary to look forward and to reason upon the future effects of it; a tax which will produce ten millions, may impoverish a nation more than one of fifty, and, beyond the amount of ten millions, become a scourge; for, the government which stifles reproduction, opposes the developement of industry, and, being reduced to live upon its capital, will very soon partake of the public poverty. By whatever impost the tax upon salt may be replaced, I doubt whether one can be found more injurious in its effects. All the complaints that are made in regard to the revenue ought to be directed against this duty; and in order to hasten the suppression of it in the country, the tax might be kept up on the consumption of the towns, where salt forms but a small part of the expense of each household.

There is, at this day, much inquiry whether the division of landed property is favorable or injurious to agriculture. This division is the necessary consequence of the partition of successions in a direct line, and of the sale of detached portions of great estates. The question of the division of property has its supporters and its opposers; but I believe that it is from not having viewed the subject in its true light, that opinions in regard to it are still divided. Wherever labor is abundant; wherever the cultivation of grain and of artificial fodder cannot be carried to its full extent; wherever the nature of the soil admits only, or mostly, of the cultivation of the vine, there the division of property is advantageous. The impossibility of feeding animals for labor, in such situations, calls the arm of man into use to supply their place; and the husbandry on a small scale thus practised, fertilizes a soil, which would otherwise remain sterile. A small estate, placed in the hands of an industrious and intelligent man, will always produce more than if it were annexed to an extensive domain. The children of the proprietor of a small farm will collect manure for the fields, or clear them from noxious weeds: the father of the family will till the soil with care, and at the most favorable seasons; he will not leave a corner of his ground unproductive. Under this kind of management four or five acres of well-cultivated land is sufficient for the maintenance of a family; whilst fifty, in a farm, the labors of which are carried on upon a large scale, requiring the assistance of animals, will scarcely support five or six.

If we consider the division of property in its moral relations, we shall find its advantages greatly increased. The laborer without property has no country; he remains fixed to no point excepting by habit; his means of subsistence are everywhere, where he can employ his strength; the laws are for him only modes of oppression; disorder and insurrection present to him some chance of ameliorating his condition, and he is always at the disposal of those who will pay him best.

Landed property, whether it be extensive or not, by attaching the owner of it to the soil, causes him to love the government which protects it, and to respect the laws which guarantee its possession. Since the number of proprietors of land in France has been tripled, the leaders of insurrection amongst the people have not, in the country, found any support.

In a neighboring kingdom, where they count scarcely twenty-five proprietary families, and where manufacturing industry employs the greater part of the population, the government is obliged to levy a tax of nearly three hundred millions of francs, in order to give bread to the vagrant portion of the community, and thus to secure the public tranquillity. In Spain, where the nobility and clergy possess nearly all the landed property, we see the population besieging the gates of the castles and convents, to ask alms from the monks and nobles. Without doubt the greater part of the wealthy are not insensible to the cries of misery which surround them; but it is surely better for each one to derive his subsistence from his own resources, than to beg it from another. I do not pretend, that it would be of advantage to divide all the French territory into small estates, or to reduce it everywhere to the mode of culture adapted to them: those portions of country, which admit of the full developement of great agricultural resources, ought to be covered with farms of an extent sufficient to unite all the means necessary to call them into action. It is not expected that it will be possible, except on these great farms, to raise cattle, or to supply all the requisites of life for the markets. The present state of things has established itself by its own fitness: the difference between those portions of country suited to great, and those adapted to small cultivation, is so well felt, that the division of real estate into small farms is only found in the last. Private interest has placed the bounds of the subdivision of territory; and it can be safely left to that great mover of the conduct of men, to stop the further division at that moment, when the processes of labor can be carried on with the most ease, and to the greatest advantage. If exchanges should become less difficult than at present, there is no doubt that contiguous portions of land, belonging to different proprietors, would be united under one, till a farm of convenient extent should be formed.

The progressive steps in agriculture are, and ought to be, slow; and it is contrary to the counsels of wisdom and prudence, to wish to deviate from customs rendered sacred by time, until the new modes to be adopted shall have received the sanction of successful experiment.

The reproach, which is every day made to the husbandman, of his indifference towards new modes of culture, appears to me not to be well founded; he wishes first to see and compare them with the methods to which he has been accustomed; he has neither the knowledge, nor the means of forming beforehand a just estimate, of the advantages which they offer him; he perseveres then in his old course till some neighbour, richer and more enlightened than himself, is able to present to him, by the new mode, results more advantageous than he has obtained from his own.

Example is the only lesson profitable to a husbandman; when one is placed before his eyes, and his reason is convinced of its goodness, he is not slow to follow it; and by no other way than this, can improved methods of agriculture be introduced and propagated.

The civil discords which have so long agitated France, have compelled a great number of proprietors to abandon the stormy life of the city, and to establish themselves in their domains, where they direct the labors of their farms; agriculture is thus enriched by the intelligence, the wealth, and the scientific views, which they carry with them to every part of the country. It is much to be desired that this course should be generally pursued, since it cannot but have a happy effect upon agricultural prosperity, and thus ultimately benefit the kingdom at large.

Without doubt the superintendence of the labors on an extensive domain, by an enlightened owner, is beneficial to the advancement of agriculture; and at the same time that it is one of the most useful, it is one of the most delightful and noble of all occupations; but if the improvements, which the proprietor of a large estate can introduce, do not compensate for the advantages which the small proprietor or farmer has over him, the former may sacrifice his interests. The proprietors of small farms are constantly at the head of the laborers, and themselves assist in the performance of the work; they live at small expense, attend fairs and markets frequently, and buy and sell to advantage; they have no overseers to pay, nor to feed; their wives and daughters take care of the poultry-yard and dairy, and perform the labors of the house; such are happy, when, at the end of a year, they find some profit arising from the labors of themselves and families. The large proprietors, whose possessions are intrinsically of greater value, do not enjoy any of these advantages; and, if they do not compensate for the absence of them by the exercise of a superior kind of industry, they must sustain loss, where the husbandman derives gain. In order to ensure success in any undertaking, it is not sufficient to adopt a new method of proceeding. In agriculture, as in every well-conducted enterprise, every thing should be calculated, and the operations to be entered upon should be regulated by a comparison of an estimate of the expenses attending them, with an estimate of the profits which may be rationally expected to arise from them. Though a paradoxical statement, it is certainly true, that a farmer may be ruined by a good harvest;

and it is equally as true, that agriculture does not require unnecessary expenses; on the contrary, she condemns every superfluity as a species of luxury. It is from their not being fully impressed with the importance of these principles, that we every day see new proprietors condemn, almost without examination, usages consecrated by time and accredited by good results, to introduce, at great expense, innovations unsuited to the soil or climate. Being unable to bring these into coöperation with their plans, they are obliged to abandon their estates after having ruined their fortunes.

One of the causes, undoubtedly, which contributes most to retard the application of just principles to French agriculture, is the shortness of the leases; which hardly allowing a farmer to become acquainted with the nature of the soil, he cultivates it nearly at hazard; he can neither make any improvements in his modes of dressing the land, nor establish a good system of cropping; he is obliged to forego the use of the best kinds of grasses, such as sainfoin and clover, because he cannot, in a short space of time, prepare the land for the reception of them; neither can he hope to reap the benefit of the harvests, which they would, for a long time, produce. Thus, however intelligent a farmer may be, he is forced to live from day to day, and continue the imperfect system of cultivation commenced by his predecessors. He is obliged to obtain from the soil the utmost that it can furnish, in the state in which he takes it, without making any efforts to ameliorate the condition of the soil; since at the end of his lease he would be liable either to have his rents raised in proportion to its increased productiveness, or to have his lease taken from him.

Whilst the cultivation of artificial meadows, and the sound doctrine of a rotation of crops, were unknown, it was well to fix the duration of leases to three years; then all agriculture consisted in two years of corn harvests and one year of fallow; the same course recommenced every fourth year, and the successive farmers followed this plan without any deviation; there was therefore no inconvenience arising from supplying the place of one by another. But at this day it is well known, that the establishment of artificial meadows, and a good system of successive crops, ought to form the basis of agricultural proceedings; and it is acknowledged, that in order to execute these two great methods of amelioration, and to reap the fruits of them, a term of twelve or fourteen years is necessary; the leases ought, therefore, to be of at least that duration. In cases like this, the interests of the proprietor and farmer are the same, nor can they be divided without injury to both. Ground well tilled increases in value, and thus enriches both the lessor and the lessee, whilst on those estates where the farmer sees himself secure of remaining for only three years, he cannot employ either his intelligence or capital to advantage; and he continues the imperfect course of management which he has hitherto pursued.

Though agriculture has been gradually enriched by the introduction of many foreign plants, it still remains for us to adopt and naturalize others, and to extend the cultivation of those we now possess. The agriculture which is limited to the production of grain, supplies only a portion of the wants of society; but if it includes in its labors all the productions of which the climate and soil will admit the cultivation, it will provide for the workshop of the artisan the materials of his industry, and thus supply every necessary of life.

The lot of the agriculturist who cultivates only one species of produce, is always precarious; he is dependent not only upon the chances of the harvest, but upon the rate of sales and the necessities of consumers; whilst he who can procure from the soil a variety of productions, is nearly sure of obtaining a market for some of them. It is thus at the south, where, independent of the productions common to all the country, the large proprietor has still his harvests of wine, silk, and oil, and is indemnified by the abundance of one of these for the mediocrity of the others.

Another advantage resulting to the agriculturist from the cultivation of a variety of productions, is the power of appropriating each portion of the land to the vegetable for which it is best adapted, and, by this means, of preserving the soil in good condition. This mode of management offers to the agriculturist immense resources for a rotation of crops; where only grains are cultivated, it is impossible to establish a judicious succession of crops; since it is only upon a variety of productions that there can be founded that system of rotation or succession, which will preserve the land in a constant state of fertility, and permit it to produce without interruption. We have already introduced into agriculture the cultivation of grasses, grains, oil, and roots, and have thus furnished the materials for a succession of crops. We have for a long time raised flax, hemp, madder, and hops; but we are still obliged to purchase of foreign nations the greater part of those articles. Why cannot the soil of France furnish all we need of them? Neither land nor hands are wanting to carry French agriculture to perfection; the variety of the climate, the nature of the soil, the intelligence of the inhabitants, all permit the cultivation of nearly every thing which the wants of society require. In regard to position, France enjoys a privilege which no other nation can partake with her.

I propose closing this work with two treatises; one upon the extraction of indigo from woad, and the other upon the manufacture of sugar from the beet root. These two branches of industry can yield to the agricultural interests of France an annual product of more than a hundred millions of francs. I shall submit to the agriculturist the information which experience has afforded in regard to these new sources of prosperity; and I do not doubt, if he will direct his attention to the subject, that he will appropriate a portion of the time included in his rotation of crops, to the cultivation of two such important articles of importation.

Whilst endeavouring to improve agriculture by applying to it the physical sciences, I have striven to avoid those stumblingblocks which would infallibly have turned me aside from the end which I proposed to myself to attain. I have endeavoured to keep in view, that I was writing for the agriculturist; and that consequently my work ought to be clear, precise, and suited to his understanding, his education, and his means. In order to effect this, I have often borrowed his language, and I have nearly always relied upon his experience for the truth of the principles which I have advanced. Convinced that a process, the results of which have been proved, is at all times preferable to a purely theoretical statement, I have uniformly respected the knowledge acquired by experience, and have proposed no new methods, excepting those, the superiority of which over the old ones appeared to me to be fully confirmed. It is particularly important in agriculture to be cautious of innovations. There is not amongst husbandmen, generally speaking, a sufficient degree of knowledge to enable them to appropriate the suitable soil and climate to foreign productions; their best plan therefore is, to wait till some neighbour more enlightened than themselves can exhibit to them specimens of improvements; which they may imitate without running much risk of ill success.

I shall perhaps be accused of having permitted myself to make some repetitions, and I candidly acknowledge that I have not endeavoured to avoid them. In a work like this, the subjects which are treated may often be presented under different forms; their phenomena always result from the same principles, but they may be most clearly elucidated by varying the modes of explaining them. I have treated each subject in a manner entirely independent of the rest; I have called to mind all the facts that could throw light upon it; I have deduced from them those principles which ought to direct the agriculturist in his labors; and I have not feared to repeat a truth as often as I thought it could be done with advantage.

This work is not perfect, and I can myself judge of its imperfections better than any one else; but, such as it is, I believe it will be found useful. I trust that the application of the physical sciences to agriculture will be extended in proportion as those sciences advance; and that a more thorough knowledge of the principles according to which they act, will occasion the rectification of any errors which may have arisen from their having been misapplied. The celebrated Davy, of England, has already published a work upon Agricultural Chymistry, from which I have borrowed many excellent principles: others will do better than we have done.

Hitherto the physical sciences have been applied to the other arts much more than to agriculture; many arts have, in our day, been originated or improved, by their means, whilst the progress made in agriculture has been very trifling. This difference appears to me to proceed from two causes: the first of which is, that the greater part of the phenomena offered to us by agriculture are the effects of the laws of vitality, which govern the functions of plants, and these laws are still unknown to us; whilst, in the arts which are exercised upon rude and inorganic matter, all is regulated, all is produced, by the action either of physical laws only, or of simple affinity, which are known to us. The second cause is, that in order to apply the physical sciences to agriculture, it is necessary to study their operations profoundly, not only in the closet, but in the fields.

Though the proprietor of a large domain, of which I have for a time directed the labors, I feel that the facts which I have been able to collect upon various subjects, are still insufficient for the establishment of indisputable principles regarding them; and in all such cases, I have done nothing but present to the reader the doubts or the simple probabilities which may have arisen from my observations. I may have committed many errors in my explanations, but I believe I have not misstated a single fact; and it is in this belief that I offer this work to the agriculturist.

CHYMISTRY

APPLIED TO

AGRICULTURE.

CHAPTER I.

GENERAL VIEWS OF THE ATMOSPHERE, CONSIDERED IN ITS EFFECTS UPON VEGETATION.

In order to judge of the influence which the atmosphere exercises over vegetation, it is necessary to be acquainted with the peculiar and characteristic properties of each of the elements of which it is composed, and to study their action upon terrestrial bodies.

The gases, azote and oxygen, are the two fluids, of which the atmosphere is essentially composed; they are found in uniform proportions, even in the highest regions from which they have been brought. M. Gay-Lussac has established this fact, by a comparative analysis of the air taken from a height of twenty-three thousand feet, and of that which is upon the surface of the earth.

There are certain other fluids, which are uniformly found in the atmosphere, but in very variable proportions; the principal of these are carbonic acid, water, the electric and magnetic fluids, light, and heat. The two last mentioned exercise a very marked influence, not only on vegetation, but on all the phenomena which terrestrial bodies present to our notice; and though they do not enter essentially into the composition of the atmosphere, their action is so closely united with that of its principal constituents, as to be nearly inseparable from them. In order that the action of the atmosphere may be better understood, I propose to treat separately of all the fluids it contains, and afterwards to show the phenomena which the application of them to agriculture exhibits.

ARTICLE I.

Of the Ponderable Fluids contained in the Atmosphere.

The ponderable fluids contained in the atmosphere are azote, oxygen, carbonic acid, and water.

1. Azote constitutes nearly four fifths of the atmospheric composition, and yet, by a singular caprice of nature, it exercises less influence on the substances of the three kingdoms, than any one of the other principles contained in the atmosphere. This gas is found in small quantities in some of the products of vegetables, and abundantly in those of animals. The presence of azote in some of the products of vegetation is to be accounted for by its presence in the water, which plants imbibe from the atmosphere, and in those manures by which plants are nourished, and of which it forms one of the principal constituents.

In animals, in which azote is more abundant than in plants, the food by which they are nourished, and the air which is inhaled by respiration, concur equally to account for its presence. The experiments of Messrs. de Humboldt and Provençal upon fish; Spallanzani upon reptiles; and those of Messrs. Davy, Pfaff, Enderson, Edwards, Dulong, &c. upon man, leave no doubt as to the absorption of azote during respiration; but this absorption is unequal and irregular, varying according to circumstances; this gas differing from oxygen in this particular, at least in its effects upon animal and vegetable economy. The action of azote is, so far as it is known, of such trivial importance, that we are at a loss to account for the proportion which nature has assigned it in the composition of the atmosphere. It is supposed by some, that all the gases, all the vapors, and all the exhalations which arise from the surface of the earth, form in the atmosphere an immense magazine of azote, which is returned thence as it is needed, either for the support of animal and vegetable life, or to produce those phenomena of composition and decomposition, which are constantly renewing the surface of the globe. The specific gravity of pure azote is to that of the atmosphere in the proportion of 9,691 to 10,000.

2. Oxygen gas forms about one fifth of the atmosphere.

The specific gravity of oxygen is to that of the atmosphere, as 11,036 to 10,000. The effects produced by oxygen are equally numerous and important; it supports animal life by respiration; and combining with the carbon of the blood, it produces the greatest proportion of animal heat. The germination of seeds is promoted by this gas, and it is absorbed by the leaves of plants during the night: by its combination with the metals the oxides of them are formed. It is likewise the necessary agent of combustion, and concurs powerfully in the decomposition of all animal, vegetable, and mineral substances.

In all cases where oxygen exerts its action, it combines with some one of the elements upon which it acts, forming acids with carbon, azote, sulphur, phosphorus, and many of the metals; water with hydrogen, &c. The nature of the compositions, of which oxygen is an element, varies according to the proportions in which it enters into combination.

When we survey the extent and importance of the operations performed by this gas, and especially when we consider that it is constantly forming new bodies, with which it afterwards ceases to have any connexion, we are almost led to fear, that the atmosphere must be, sooner or later, exhausted of this active and regenerating principle; but nature, we find, is continually repairing the loss thus sustained, by the production of equivalent quantities. The leaves of plants, under the influence of the solar rays, pour forth into the atmosphere torrents of oxygen, produced by the decomposition of carbonic acid and of water; of which they appropriate to themselves the carbon and the hydrogen.

It is without doubt possible, that in many situations the reproduction of oxygen is not in proportion to its consumption. This must happen especially where great quantities are required for respiration, or to support combustion. But this deficiency is only partial and momentary; for the great mobility of the atmospheric fluid enables it, almost immediately, to restore its equilibrium from all points. The agitation of the winds mixes together, in proportions nearly constant, both the elements of which the atmosphere is composed, and the principal fluids which are found in it.

The creation or destruction of any element is not to be found in the operations of nature. The numerous phenomena of composition and decomposition, which take place upon the surface of the globe, present only changes of combinations, which are formed according to fixed, eternal, and unchangeable laws. Thus nature is regenerated, without being impoverished ; and matter experiences only those changes which are reproduced uniformly and periodically, especially in organic bodies.

3. Carbonic acid is found constantly, but in various proportions, in the atmosphere. Though much heavier than azote or oxygen, its weight being to that of the latter, as 1,520 to 1,000, it is found disseminated throughout the whole atmospheric region. The elder M. de Saussure has, by means of lime-water, drawn it from the air upon the summit of Mont Blanc. From the results of all the experiments that have been made, there can be no doubt, that the proportions of azote and oxygen in the composition of the atmosphere are uniform and nearly invariable ; and it appears to be likewise proved, that carbonic acid is also found there, and at all heights, but in various proportions.

M. Th. de Saussure has compared the different portions of carbonic acid in the atmosphere which he has analyzed, and found the difference between them, in summer and in winter, to be as follows.

IN WINTER.

31st of January, 1809, 10,000 parts of air
contained . . . . carbonic acid 4,570
2d of February, 1811 . . . . . . " " 4,660
7th of January, 1812 . . . . . . " " 5,140

The mean term in winter from 10,000 parts of air was,
In volume . . . 4,790
In weight . . . 7,280

IN SUMMER.

20th of August, 1810, 10,000 parts of air
contained . . . . carbonic acid 7,790
27th of July, 1811 . . . . . . " " 6,470
15th of July, 1815 . . . . . . " " 7,130

The mean term in summer from 10,000 parts of air was,
In volume . . . 7,130
In weight . . . 10,830

Without doubt, when the air is tranquil, or when the carbonic acid, which is produced so abundantly by fermentation, respiration, combustion, &c., is retained in confined places, the quantity of this acid will exceed the ordinary proportion; but from the moment that the agitation of the winds can mingle it with the atmosphere, it is spread and diffused towards all points, according to certain fixed laws. Unless in some extraordinary cases, which form exceptions to the general rule, carbonic acid exists in the atmosphere at most only in the proportion of $\frac{1}{500}$.

Carbonic acid is constantly absorbed and decomposed by the leaves of plants. The carbon is appropriated by the plants to their own support, and the oxygen is thrown out into the atmosphere. Carbonic acid combines with the lime in fresh mortar, and causes it to return to its original state of lime-stone. Under the pressure of the atmosphere, water will hold in solution nearly its own volume of carbonic acid, and be slightly acidulated by it; but under the force of a greater pressure, it will contain a much greater quantity. Water, thus charged, froths like Champagne wine, which owes its effervescence to the carbonic acid produced by the fermentation of the wine in well-corked bottles. In some recent experiments carbonic acid gas has been reduced by compression to a liquid state.

4. Water exists in the atmosphere, under the form of an elastic fluid. When it is absorbed by bodies for which it has a strong affinity, such as the calcined muriate of lime, the portion of air from which it is taken, is diminished in weight and volume. This has been proved by the experiments of the elder M. de Saussure and of Davy. The quantity of aqueous fluid contained in the air, varies according to the temperature of the atmosphere, and increases in proportion as that is elevated. At 50° Fahrenheit it forms in volume nearly $\frac{1}{50}$ of the atmospheric fluid; and as its density is to that of the atmosphere in the proportion of 10 to 15, it constitutes nearly $\frac{1}{75}$ of its weight (Davy).

The aqueous fluid forms, when the atmospheric temperature is 34° Centigrade = 93°.20, (Davy says at 100°,) $\frac{1}{14}$ of the volume of the air, and $\frac{1}{21}$ of its weight.

The elder M. de Saussure, in his beautiful *Treatise upon the Hygrometer*, has determined the weight of the water contained in a cubic foot of air, at different temperatures, and has prepared the following table of the results.

Degrees of the hygrometer.	Weight of the water contained in a cubic foot of air at 66°.2 Fahrenheit.	Weight of the water contained in a cubic foot of air at 45°.9 Fahrenheit.
	Grains.	Grains.
10	0.4592	0.2545
20	1.0926	0.6349
30	1.7940	1.0833
40	2.5634	1.5317
50	3.4852	2.0947
60	4.6534	2.7159
70	6.3651	3.3731
80	8.0450	4.0733
90	9.7250	4.9198
98	11.0690	5.6549

"Consequently," adds M. de Saussure, "I do not think we are far from the truth, in assigning 11 grains of water to saturate a cubic foot of air, at the temperature of 15° of Réaumur," (=65°.75 Fahrenheit.) "The solution of these 11 grains of water in a cubic foot of air at the temperature of 15° Réaum. (= 65°.75 F.) increased the density of the air so much, that the barometer, which before was at 27 in., rose to 27 in. 5 lines 79,411, that is to say, about 27 in. 6 lines; consequently, the density of the air, or its volume in the receiver, was increased about $\frac{1}{54}$."

When the temperature of the air is diminished, the aqueous fluid is condensed, and appears in the atmosphere in the form of vapor, and is deposited in the state of dew. The moisture of the night air from this cause, during the heat of summer, restores vegetation from that state of languor produced by the too great warmth of the day.

Oxygen and azote have been classed among the simple bodies; carbonic acid and the aqueous fluid among the compound bodies, of which the principal constituents are known, and which can be formed and decomposed at will.

100 parts of carbonic acid contain;	. . . carbon	27.36
	. . . oxygen	72.64
100 parts of water contain	. . . hydrogen	11.06
	. . . oxygen	88.94

Oxygen and azote constitute, essentially, the atmosphere; since, when the two other principles are separated from it, it still retains nearly all its characters of form, elasticity, &c. It however loses its most important powers of influencing vegetation; so that all the substances found in the atmosphere are necessary to the production and renewal of the phenomena which the three kingdoms present to us.

Of the four principles of which I have just spoken, as constituting the atmosphere, the aqueous fluid is that which appears to be the least closely united to the others; since a change of temperature alone is sufficient to produce a change of its proportions; whilst azote, oxygen, and carbonic acid preserve, always, nearly the same relative proportions; nor can they be varied, or disunited, by means of compression or change of temperature. The aqueous fluid does not rise to a great height in the atmosphere; for, according to the reports of those experimentalists who have arrived at their conclusions by the assistance of air-balloons, the higher regions of the atmosphere are very dry, so as to produce, by the avidity with which they absorb the moisture from the boat of the balloon, a warping and cracking of its boards, as if they had been exposed to a strong heat. This effect is produced by the dryness of the atmosphere and the diminution of its specific gravity.

The manner in which the atmospheric elements are united is worthy of notice. This union is sufficiently strong to counterbalance the difference in their specific gravities, and not to allow them to be separated by compression, or the tumultuous agitation of the air; and yet it permits the various principles to be decomposed and isolated, by presenting to them bodies for which they have some slight affinity. Thus, if we inclose under a bell-glass any volume whatever of atmospheric air, the aqueous fluid may be extracted from it, by the calcined muriate of lime. The combustion of phosphorus in it will absorb the oxygen gas; lime-water, or the caustic alkalies, will combine with the carbonic acid; and nothing will remain but azote, which is the portion that has the least tendency to form combinations.

This weak state of union among the principles contained in the atmosphere is necessary, in order that they may exert their powerful and constant action upon all the various bodies which cover the surface of the globe; the composition and decomposition of which cannot be effected otherwise than by the means of these agents.

Independently of those bodies which essentially constitute the atmosphere, there are mingled in it the exhalations constantly arising from the earth; these are again disengaged from the air, and precipitated, as soon as the heat, or any other cause which occasioned their ascension, ceases to act upon them. These exhalations modify the properties of the air, and affect its purity. The oxygen and the water of the atmosphere become impregnated with the particles of the exhalations which are deposited with them upon the surfaces of other bodies, where they remain in contact, or enter into combination, with them. The origin and dissemination of many maladies may be traced to this source; the germ of them is carried through the air by the aqueous fluid. And for the same reason it is, that intermittent fevers are endemic in those situations, where large quantities of animal or vegetable matter are undergoing decomposition, as upon the borders of ponds and marshes; and that the miasm, which arises from numerous animal remains in a state of decomposition, becomes a fruitful source of disease. It is for the same reason also dangerous, under some circumstances, to breathe the evening air; the aqueous fluid contained in it is loaded with the noxious principles, which the heat of the sun during the day had caused to ascend into the atmosphere. The disagreeable odor, conveyed to us in mists, is owing to the power of the aqueous fluid in transmitting the exhalations arising from the earth.

The manner in which the air conveys to us the perfume of plants, and the odor which it contracts from the exhalations of bodies in a state of decomposition, indicate clearly its influence in producing maladies, and still more plainly its power of propagating those that are contagious.

ARTICLE II.

Of the Imponderable Fluids contained in the Atmosphere.

Besides the ponderable substances which constitute the atmosphere, and those which are found in it accidentally, it receives some imponderable fluids, of which the effects are less known, but which appear to play an important part in the atmospheric phenomena; of this number is the electric fluid.

1. Electricity is developed by friction, and transmitted by simple contact. It is accumulated in bodies when they are insulated; and it is communicated in the same manner as heat, when bodies which are non-electric approach those which are electric.

The singular properties of the electric fluid contained in the atmosphere, and the frequent variations which it undergoes, give rise to numerous phenomena, for which observation and experiment enable us to account. When this fluid is abundantly diffused throughout the atmosphere, it exercises a powerful influence over vegetation, excites the action of oxygen, and determines the condensation of the aqueous fluid. Davy has observed that grain germinates more quickly in water charged with positive electricity, than in that which contains the opposite principle; and that it is a well known fact, that fermentation takes place most rapidly during a thunder-storm, and that a liquid, composed of a variety of principles not very closely united, milk for instance, is decomposed, and becomes acid under a highly electric state of the air.

2. Whatever may be the opinion we may adopt, as to the nature of the principle of heat, there can be no doubt that there exists in the atmosphere, and in all terrestrial bodies, an imponderable fluid, unequally imparted to them, and which renders their state solid, liquid, or gaseous, according as the affinity, existing between their particles and the fluid of heat, is more or less strong. It is this state which we regard as the natural state of bodies.

Exposed to an equal degree of atmospheric temperature, all bodies, in their natural state, are penetrated by unequal quantities of the fluid of heat; but as the fluid is in combination with the particles of the bodies, and thus forms one of their constituent principles, it does not develope its most important property, which is that of heat; and in this state it has been agreed to call it *caloric*, and it only takes the name of *heat* when it is free, and disengaged from all combination.

Caloric, interposed between the molecules of bodies, tends to separate them from each other; and when accumulated beyond its natural quantity, the excess acts as heat; changing the form of bodies, and causing them to pass from the solid to the liquid state, or from the last to that of vapor.

Those bodies which exist naturally in a gaseous state, and which are rendered solid by being brought into combination with other substances, return to their natural state as soon as a sufficient degree of heat is applied to destroy the force of the affinity which unites them to their base. But those which are not originally gaseous in their form, under the influence of heat pass through all the degrees intermediate between their natural state and that of imperceptible vapor; and return to the concrete state when deprived of the excess of heat which had been applied to them.

Caloric can be extracted from bodies by percussion or compression, in the same manner as water is expressed from a substance which has imbibed it. When a body is deprived of its caloric by either of these means, the molecules composing it are brought closer to each other, and its porosity, and consequently its volume, diminished. The act of striking or rubbing hard bodies together, produces the same effect; the portion of caloric, which is in either case set free, acts as heat.

The temperature of bodies can be lowered, or elevated, by placing them in contact with other bodies more or less hot than themselves. The fluid of heat will pass from one to the other, and produce an equilibrium in their state, according to their respective capacities for caloric, which enable them to absorb unequal quantities of it.

All bodies in their natural state contain a determinate portion of caloric; but when their density undergoes a change, by the variations of temperature to which they are exposed, they lose or absorb caloric, in proportion to their contraction or dilation. The gases, which become solid by entering into combinations, the vapors which are condensed, the solids which are contracted, impart to the air a portion of their caloric, which becomes heat; whilst all these bodies, on receiving heat from the air, are dilated.

The phenomena of composition and decomposition, which uninterruptedly renew the surface of our globe, give rise every moment to the emission or absorption of caloric. Two substances, entering into combination, form a compound which perhaps requires more or less caloric than is contained in the two component principles; and then either heat or cold is necessarily produced during the operation. Those gases, which become solid by entering into combination, part with their caloric whilst undergoing the change, and thus produce heat. In combustion, where oxygen is the principal agent, there is a constant disengagement of caloric, because that gas, in general, forms solid or liquid compounds with combustible substances; and it gives out a portion of the caloric which preserved it in its gaseous state.

These principles established, we can easily explain a part of the effects produced upon vegetation by the variations of temperature.

The changes of temperature, experienced by the atmosphere in the course of a year, are so great, as to cause some liquids to pass alternately either to the solid or aeriform state, and some solid bodies to become liquid. The natural effect of heat upon these bodies is, by dilating them, to weaken the force of cohesion which unites their molecules, and, by facilitating the action of chymical affinity, to enable them to enter into combination with foreign bodies. Thus heat renders the juices of plants more fluid, and facilitates their circulation through the cells and capillary vessels; and, by giving activity to the suckers of roots, enables them to draw from the earth the juices necessary for their nourishment.

Above a certain temperature, heat, by promoting evaporation, causes the juices of plants to become thickened and dried in their organs, and thus vegetation is arrested, and life suspended. This effect always takes place during great heats, when neither rain, dew, nor irrigation can sufficiently repair the loss occasioned by evaporation. This effect would be more frequent, if provident Nature did not employ means to moderate the action of heat.

The first of these means is the transpiration of the vegetables themselves, which cannot take place without carrying off a large portion of heat, and thus preserving the transpiring body at a temperature below that of the air. The second means is found in the organization of leaves, which are the only parts of a plant where transpiration takes place. That surface of leaves which is exposed to the direct rays of the sun is covered by a thick epidermis, which resists the calorific rays. In herbaceous plants, as in the stalks of grasses, this covering is composed principally of silex. In other plants it is analogous to resin, wax, gum, or honey; whilst the epidermis, which covers the opposite sides of the leaves, is fine and transparent.

It is by this, that transpiration and the absorption of nourishment from the atmosphere are carried on. If we should reverse the order of things, and present the under surface of a leaf to the rays of the sun, we should very soon see that it would make great efforts to resume its natural position.

When a plant is dead, or rather when an annual plant has fulfilled its destiny, giving assurance of its reproduction by the formation of its fruit, the action of heat and of the other chymical agents is no longer modified by any of the causes of which I have just spoken, and the plant receives their impression in an absolute and unmodified manner. When the temperature of the atmosphere sinks below a certain point, the fluids in plants become condensed, the movement of the juices is retarded, the activity of their organs languishes, and is at length suspended, until restored by the return of heat. The action of the atmosphere upon plants, when deprived of its due proportion of heat, is however modified by the emission or disengagement of caloric, which is always given out when liquids are condensed, or solids contracted; and this occasions the temperature of plants, during the winter, to be always a little higher than that of the atmosphere.

It sometimes happens that the temperature of the atmosphere sinks so low, as to produce fatal effects upon plants by freezing their sap, and thus occasioning their death. This effect does not always depend upon the intensity or degree of cold to which they are exposed, but upon particular circumstances. I have seen olive trees resist a temperature of 22°.2 Fahrenheit, and perish from that of 28°.6, because in the last case the snow, which had collected upon the branches of the trees during a night, was dissolved the following day by the heat of the sun, and the wet tree was exposed during the succeeding night to the action of 28°.6. There is nothing more dangerous for corn and grasses, than those frosts which follow immediately after a thaw, because the still wet plants, not being deeply rooted in the ground pulverized by the frost, have no means of defending themselves from the effects of the cold.

3. Sennebier was the first to admit that the influence of light was hurtful to the germination of seeds. Ingenhouz confirmed this opinion by actual experiment; but M. de Saussure, who caused grains to germinate under

two receivers, the one opaque, and the other transparent, is convinced that germination took place in both cases at the same time; but that the subsequent vegetation was more rapid and vigorous under the transparent, than under the opaque receiver. It is easy to reconcile these opinions and results, though apparently so contradictory, by separating the action of heat from that of light. As plants transpire very little during their first stage of germination, if they are exposed to the united influence of the two fluids, that of heat will exercise upon them its full force, because there is no evaporation from them to temper its effects, and their delicate organs will be withered and dried up. It is for this reason that gardeners are so careful to shelter their nurseries from the rays of the sun, and not to expose their plants, till by the develpement of their leaves they are able to moderate the effects of heat by transpiration.

Though the action of light upon vegetation does not appear to be so important as that of the other fluids of which I have spoken, it is not in reality less so. Plants, which are raised in the shade or in darkness, are nearly or quite without color, perfume, taste, or the firmness of texture of those, that are exposed to the direct rays of the sun; and if the luminous fluid does not combine with the organs of plants, we cannot deny that it is a powerful auxiliary in their combinations.

It is generally acknowledged that plants do not emit oxygen gas, excepting when exposed to the direct rays of the sun; and it is known also that flowers rarely produce fruit, if raised entirely in the shade. According to the observations of M. Decandolle, the sensitive plant, if carried into the shade, closes its leaves as during the night, and reopens them immediately upon being again exposed to the rays of the sun or of a lamp.

The grand discoveries of Herschel have thrown great light upon these delicate questions. That learned philosopher has proved, that amongst the various rays constituting a pencil of light, there are some that possess nearly exclusively the property of being luminous, others, that of affording heat. Wollaston and Ritter have added to these important facts, that there exists a third species of rays, which appear to act upon bodies as powerful chymical agents.

When we reflect upon the influence which the atmosphere exercises over vegetation and over the principal operations which are carried on in rural establishments, such as fermentations, the preparation of various productions, and the decomposition of some substances, in order to apply them to particular purposes; we are astonished at finding nowhere any of the simple and unexpensive instruments which announce its changes every moment.

I do not propose that delicate or complicated instruments should be provided; but I wish to find on every farm an hygrometer, to ascertain the humidity of the atmosphere, a thermometer to indicate the changes of temperature, and a barometer to determine the weight of the atmosphere. This last instrument would be particularly valuable, as predicting the changes of the weather; the rising of the mercury announces the return of dry weather, and its sinking warns us of rain and storms. We can regard these variations but as signs; but they are signs much more certain than those which country people derive from the changes of the moon.

CHAPTER II.

OF THE NATURE OF EARTHS, AND THEIR ACTION UPON VEGETATION.

Nearly all vegetables derive their support from the earth. There are however some, the seeds of which, being deposited upon trees by birds or by the winds, germinate and grow, appearing to be in the situation designed for them by nature; such are the mistletoe, the mosses, &c. There are others that float upon the water, or fasten themselves upon dry rocks, upon slates, or tiles; of the last kind are the fleshy plants. As the earth furnishes the greatest number of plants, and all those which are of the most importance to man, its influence upon vegetation is of the greatest consequence, and at the same time one of the most difficult things of which we can treat.

Plants are not, like animals, endowed with powers of locomotion; but are always fixed to a limited portion of the soil. They depend upon the small space which they occupy for the supply of their wants; they can place under contribution only those portions of the surrounding air, earth, and water that come in contact with them; it is necessary, then, that they should find immediately around them the nutritive principles requisite for their growth, and for the exercise of their functions; it is necessary that they should be able to extend their roots, in order to draw from the soil its nourishing juices; and to fasten themselves in the earth, so as to be secure from being dried up by heat or uprooted by the winds.

As all the qualities required by a vigorous vegetation cannot always be found united in land appropriated to cultivation, we are led to examine the nature of earths, and the differences which exist among them.

ARTICLE I.

Of Mould.

All plants, when dead, are more or less readily decomposed; and in undergoing these changes, which are greatly facilitated by air and heat, they form products with which it is of importance for us to be acquainted; as the principal aliments of living plants are furnished by those that are dead. Decomposition is most rapid in succulent vegetables, and in those which are collected in heaps; but a high degree of atmospheric temperature and the humidity of plants contribute powerfully to accelerate it. During decomposition much carbonic acid is given out; a part of this exists in combination with the constituent principles of the plant, and a part of it is produced by the action of the oxygen of the atmosphere upon the carbon of the plant; hydrogen, which is probably furnished by the decomposition of the watery particles, and is generally carburetted, is likewise exhaled, as also ammoniacal gas when its elements exist in the plant. When large masses of vegetables are in a state of fermentation, heat is always produced; but if they have been dried, it is necessary to collect them into heaps, and moisten them slightly in order to determine their fermentation and decomposition; in this case the heat produced is sometimes so great as to cause the combustion of the mass; a phenomenon which occurs when hay is stacked without being sufficiently dry, or when ropes, hemp, or flax are piled up wet.

When all the parts of a plant are decomposed, there is produced an earthy residuum of a brown color, which is called *mould*. In this, besides the salts and the earths which it contains, are found some oils and extractive principles which escape decomposition.

The distillation of mould in a retort, produces much carburetted hydrogen, some carbonic acid, a bituminous empyreumatic oil, and some water holding in solution pyroligneous acid and carbonate of ammonia.

The analyses by fire do not produce any substances, such as exist in vegetables and animals; they decompose the natural products of the plant, and present their elements under different combinations. The analysis of mould by washing in water, leads us to a better knowledge of its component parts, and of its actions upon vegetation. M. de Saussure found, that pure mould, formed in an open field, leached twelve times with boiling water, yielded a dry extract equal to $\frac{1}{11}$ of its weight; rich garden soil, and the light soft earth from a field which bore a good crop, yielded the same extract, but in less quantity. This learned philosopher is convinced, that the excellence of mould does not depend upon the proportion of the extractive matter which it contains.

Mould furnishes by distillation nearly the same principles after being deprived of its extract by washing, as before; but its powers of supporting vegetation are less in the first case, than in the second.

When, after repeated washings, no more extract can be obtained from mould, it is only necessary to moisten it, and leave it exposed to the air for three months, in order to have it yield fresh supplies. These macerations, continued for a long time upon the same mould, have always produced colored infusions, approaching in their qualities to the extract, (Saussure,) which proves that new combinations are formed by the successive changes of vegetable products, and that the result of these combinations is soluble in water, after it appears to have exhausted its solvent power upon the bodies. This fact is the more important, as it shows that the nutritive quality of vegetable manures may continue during the whole time of their decomposition, because they form new products soluble in water, which will afterwards serve as nourishment for plants. This fact proves still farther, that some substances, by their nature insoluble in water, may form excellent manures during the various stages of their decomposition, by giving rise to the formation of products very soluble.

M. de Saussure found, that mould which had been deprived of its extract, contained a little more carbon, than that which had not been so deprived; the former yielded $33\frac{1}{4}$, the latter 31.

One hundred parts of the dry extract of turf mould furnished 14 parts of ashes, which, when leached with boiling water, afford $\frac{25}{100} = \frac{5}{20}$ of salts composed of pure potash, muriates, and alkaline sulphates.

It is necessary to observe, that when mould is reduced to ashes, the action which water exercises upon it is in inverse proportion to the power of the heat to which it has been subjected; if that have been very intense, a sort of semi-vitrification takes place, which unites the earthy principles with the alkaline salts, and renders the mass less soluble in water. M. de Saussure has proved, that boiling water cannot extract at most more than $\frac{2}{100} = \frac{1}{50}$ of the salts contained in the ashes of mould; whilst after having obtained $\frac{1}{20}$ in alkaline salts from the dry extract of mould, by the aid of boiling water, he procured by another analytical process, a quantity of salts equal to the first.

With the exception of the earthy and saline principles contained in mould, in the proportion of 5 to 7, all the other principles are entirely destructible by the action of air and water.

When mould is exposed to the action of air, or entirely immersed in water, it suffers no decomposition; but when it is brought into contact with the atmosphere, or with oxygen gas, after having imbibed water, the oxygen combines with the carbon of the mould, and produces a volume of carbonic acid gas, always equal in volume to the quantity of water imbibed; when this water is sufficiently impregnated with carbonic acid, the volume of air enclosed under a bell glass, in contact with the mould, suffers no further change.

The carbon of which the mould is deprived by its union with oxygen, is not in proportion to the loss occasioned by decomposition; it still disengages carburetted hydrogen and water, which proves the combination of oxygen with hydrogen, and of the last with carbon. The decomposition of mould is very slow, and even when aided by the concurrence of air, heat, and water, is completed only at the end of some years.

Land owes its fertility mostly, if not wholly, to the presence, in a greater or less abundance, of principles analogous to those constituting mould. These principles are furnished by manures, and by the decomposition of plants; but each harvest causes a diminution of them, a part being washed away by rains, and a part absorbed by the crops which are raised; thus the soil is deprived by degrees of its nutritive qualities, till at length nothing remains but an earthy residuum, deprived of its nourishing juices, and completely barren; it is to restore its fertility that land must be manured afresh, after having yielded several crops.

ARTICLE II.

Of the Nature of Soils.

The question which we are now about to treat, is one of the most difficult in agriculture, but as it is perhaps one of the most important, we ought to give it the greatest attention, and to direct all our researches to proving the difference existing amongst arable lands, and their various properties.

The earth furnishes support to nearly all plants; and as each species of these requires a soil suited to its particular organs, we find that different portions of the earth differ widely amongst themselves in character. An acquaintance with the nature of soils is especially necessary, as it serves to throw light upon the cultivation of vegetables, which are principally nourished by them, and upon the suitable adaptation of which most of their properties depend.

Arable soils, which are the only ones of which I shall here speak, are generally composed of silica, lime, alumina, magnesia, oxide of iron, and some saline substances. The various characters of soils arise from the different proportions in which their component parts are combined; and the name given to each is according to that of the predominating portion of earth found in it, as siliceous, calcareous, argillaceous, &c. It is necessary that they should be classed according to their nature, that the degree of fertility of each, and the kind of cultivation to which it is best suited, may be known.

Not one of these earths is by itself well adapted to cultivation, but by their mixture they correct the qualities, or supply the deficiencies of each other; the best soil is that which unites the greatest number of the properties most suited to vegetation.

There are few soils that do not contain, in addition to the abovementioned earthy and saline principles, some portion of substances, resulting from the decomposition of animal and vegetable matter, by which, other circumstances being the same, their fertility is very considerably influenced.

ARTICLE III.

Of the Formation of Arable Lands.

Arable lands are almost entirely produced by the decomposition, from various causes, of the rocks which form the basis of our globe. The water, which flows in torrents from the tops of the mountains, abrades their sides, and detaches from them large portions of rock, which being afterward swept by the force of the current, and constantly dashed and rubbed together, have at length their corners and edges broken off, their forms rounded, their surfaces smoothed, and their size diminished, till they form, successively, pebbles, gravel, sand, and mineral slime.

The number and magnitude of the stones found in the beds thus deposited, depend upon their distance from the mountains whence they have been brought, upon the harder or softer character of the rock whence they have been broken, and upon the force of the currents by which they have been acted upon.

Nearly all the lands of our rich valleys owe their origin to the decomposition of rocks, and we can judge of the nature of the principles which compose them, by knowing those of the mountains whence they have been brought. The deposits from granitic mountains, consisting of quartz, feldspar, and mica, form soils mixed with silica, alumina, lime, magnesia, and oxide of iron. Those from mountains of the quartzeous formation are composed, almost entirely, of siliceous earth, and give rise to soils of an analogous character; and so on of the rest.

It would, however, be erroneous to suppose that the lands formed by the waste of mountains are throughout of the same nature, or contain the same principles, in the same proportions, as the rocks from which they have been produced. Upon this supposition it would be necessary that all the substances, originally contained in any one kind of rock, should be of equal specific gravity, and possess an equal affinity for water; and this is not the case. Those, the particles of which are held in the closest union, are deposited first, whilst the others are carried on by the current; silica, and the oxides of iron, predominate in those which are first deposited; then lime, alumina, and magnesia.

It is very interesting to trace the changes which take place in alluvial soils, according to their distance from the rivers which brought them; whether we consider, in these changes, the division and mixture of the constituent principles, or the varieties which they present at different distances from the sources of their origin.

Independently of the various degrees of specific gravity and hardness which exist amongst the earthy principles, there are other causes which contribute powerfully to affect the nature of alluvial lands. Rivers receive, in their courses, many tributary streams, which, mingling the fragments that they carry with the spoils of the others, modify to an illimitable extent the soils which they produce, It frequently happens, that this mixture of the mud of two rivers, produces a soil more fertile, than would have been formed by either of them singly; the qualities of one serving to correct the deficiencies of the other. Thus the washings from moutnains of the quartzeous formation, combined with the argillaceous and calcareous portions of the wrecks of other mountains, constitute a more productive soil than would be furnished by either separately.

The greatest part of those lands now appropriated to the richest culture, are but the ruins of those imposing mountains, the sides of which, rent away and carried off by torrents, are in their passage reduced to dust, and deposited in the valleys to form the basis for agriculture.

It is not possible to refer to any other causes than those I have just pointed out, the formation of the arable lands of the valleys; those which are found upon the vast table lands, which crown the tops of mountains or extend along their sides, must have had some other origin. The constant action of air and water, alone, might have produced the plains, but so gradually, that their effects would only be perceptible after a lapse of many ages, if other agents did not conspire with them to hasten the decomposition of the rocks, and to convert them into arable land.

The decomposition of such rocks, as are by their want of density permeable by water, must be much more rapid than that of those, in which the particles are more closely united; and rocks, of which the constituent principles possess some affinity for air and water, will yield much more readily to their action, than those in which no such affinity exists.

In order to account for the action of air and water, upon rocks, it is necessary to consider, that many among them contain lime, very imperfectly saturated, and usually some oxide of iron, at its lowest state of oxidation; the lime is constantly disposed to imbibe from the atmosphere its carbonic acid, whilst the oxide of iron combines with its oxygen; these combinations will be very rapid, if neither the lime nor the oxide of iron is united to any other substances, which, not possessing the same affinities for the constituents of the atmosphere, oppose its action upon them.

Rocks are frequently moistened by water for a considerable length of time, without being much affected by it; but when it has at length insinuated itself into their pores, and become there converted into ice by the cold, it destroys by its expansion the cohesion of their particles, producing rents and fissures, and thus giving access to the air, which combines with the lime and oxide of iron, and produces an immediate change in all the surfaces exposed to its action; from this moment the process of decomposition goes on more rapidly than before. The lichens and mosses, which fasten themselves upon the surfaces of rocks, continue and increase the change; their delicate roots are constantly enlarging the crevices caused by the water, by the effort they make to insinuate themselves into them; and by their decay they afford light successive layers of pulverized vegetable matter.

Water, by its own action, will penetrate by degrees into the earthy principles of rocks, and produce, at length, the effect mentioned above; but its power is wonderfully increased, whilst passing from its liquid state, to that of ice.

As soon as the surface of a rock is furrowed, and the mosses and lichens have fastened themselves upon it, all the plants which require but little nourishment, take root and decay there in turn; and the product of each successive decomposition adds something to the slight bed of earth formed by the first, till in time a soil is produced, fit for cultivation.

Hitherto we have considered only those circumstances which explain to us the formation of arable lands; these causes have, without doubt, placed at our disposal all the lands which are appropriated to agriculture; but the hand of man and the successive generations of plants have rendered them still better suited to this purpose.

The great stones which injured the harvests upon alluvial soils, have been removed by blasting. The soils which were too stiff have been improved by a suitable admixture of other earths; all the soils have been in turn manured by the remains of plants, or the collections of the barn-yard; and man has learned by experience what kind of culture, and what species of plants are suited to each soil. Nature has prepared the materials, man disposes of them in such a manner as to cause them to produce according to his necessities, or his tastes.

But in what does the difference of soils consist? and which are those best suited to agriculture?

In examining the nature and variety of the rocks, of which all arable lands were originally but the ruins; and which, notwithstanding all the labor of man, preserve their primitive characters, we shall find the following varieties.

Amongst rocks of the first formation, or, as they are called, primitive rocks, granite holds the first rank; it is generally formed by the aggregation, more or less compact, of several stones, differing among themselves in form, color, hardness, and composition; these stones are, most commonly, feldspar, quartz, and mica. These elements of granite, also, separately form rocks, in which only two of them are combined, as in micaceous schist, which is composed of quartz and mica, disposed in beds, sometimes curvilinear; quartz forms by itself, nearly without mixture, some of the primitive mountains.

I shall confine myself to these two species of rock, because the others are not so widely extended over the globe, nor do they present themselves in as large masses as these. Neither shall I speak of some substances that are found, more or less, in granite, as hornblende, amphibole, serpentine, &c., as these bodies are only secondary there.

The composition of the various stones which constitute granite, is widely different; quartz is almost entirely formed of siliceous earth ; feldspar of silex, alumina, lime, potash, and the oxide of iron ; mica contains besides these, magnesia. So that when granite is decomposed, it produces those lands which, upon analysis, afford all these principles; whilst the washings from the quartz mountains form only beds of siliceous earth; and the ruins of rocks of micaceous schist contain only the elements of feldspar and mica.

The calcareous mountains, composed of carbonate of lime, without any appearance of the remains of organized bodies, are ranged by naturalists amongst primitive rocks, and give rise to the formation of calcareous soils.

All the lands which are produced by the destruction of primitive rocks are of the first formation, and ought to be so designated to distinguish them from those which owe their existence to other causes, of which I am now about to speak.

Independently of those causes which I have just explained, and which have produced the formation of the greater part of the arable lands, there are others to which some lands owe their origin. The successive destructions which the whole surface of the globe appears to have suffered ; the decomposition of pyritous beds, which appear to have covered a part of it; the numerous lakes which have disappeared by the hand of man, or by the accidental rupture of their natural confines; the eruption of volcanoes; the overflowings of the sea ; the bony remains of animals, and the decay of vegetables buried in the ground, have formed soils of all characters; and these have afterwards been applied by man to his own use.

ARTICLE IV.

Of the Composition of Arable Lands.

It would be easy to ascertain the nature of any portion of arable land, if we had to consider only the character of the rock from which it was produced ; but vegetation, time, and the labor of man, have wrought so many changes in it, that the primitive character has nearly disappeared; and it is necessary to judge of, and appreciate it in its actual state. Still, the lands devoted to agriculture are generally composed of silex, lime, and alumina ; with these are intermixed pebbles or sand of different natures, and in various proportions, and the remains of animal and vegetable matter, more or less thoroughly decomposed. The other substances which, by analysis, are found in these soils, are not in sufficient quantities to be classed amongst their elements; when these are too abundant, as is the case in certain localities with magnesia and the oxide of iron, the soil becomes less fit for vegetation.

The best basis for good lands is a mixture of lime, silica, and alumina ; but, in order that they may possess all the desirable qualities, it is necessary that certain proportions, which an analysis of the best lands has made known, should be observed in the mixture.

I propose, in the first place, to examine in what proportions the constituent principles enter into those lands, which are the most favorable to vegetation, and afterwards to ascertain the properties peculiar to each kind of soil ; and to enlighten the agriculturist as to the best methods of correcting the faults of one, by the qualities of another. I shall then treat of the effect produced upon the fertility of soils, by the accidental deposits of animal and vegetable matter, which are mingled with them ; and I shall conclude by a short exposition of the means which can be employed by the agriculturist, for becoming acquainted with the nature of his lands.

In order to know the earthy composition of those soils, which have been considered the most fertile in various climates, I shall have recourse to the analyses of them which have been made by men worthy of the utmost confidence.

Bergmann found that one of the most fertile soils in Sweden contained

Coarse silex	30 parts
Silica	26
Alumina	14
Carbonate of lime	30
	100

Giobert analyzed a portion of fertile soil from the neighbourhood of Turin, in which the principal earths were in the following proportions,

Silica	77 to 79
Alumina	9 to 14
Carbonate of lime	5 to 12

The most fertile mixture produced by Tillet, in a great number of experiments which he made at Paris, was composed of $\frac{3}{8}$ of clay, $\frac{3}{8}$ of finely pulverized limestone, and $\frac{2}{8}$ of sand. Upon reducing these to their elements, we find

Coarse silex	25
Silica	21
Alumina	16.5
Carbonate of lime	37.5

An excellent soil for wheat, in the neighbourhood of Drayton, in Middlesex, gave $\frac{3}{5}$ of siliceous sand; the remaining $\frac{2}{5}$ were composed of three earths finely divided, in the following proportions,

Carbonate of lime	28
Silica	32
Alumina	39 *

I do not speak of the water, nor of animal and vegetable remains contained in the soil, and which enter into its composition in the proportion of about $\frac{1}{10}$.

I have myself analyzed a very fertile soil formed by the alluvions of the Loire, at a distance of three hundred and

[* Davy (*Agricultural Chemistry*, p. 162,) states this analysis thus,

	Parts.
Carbonate of lime	28
Silica	32
Alumina	29
Animal or vegetable matter and moisture	11

—Tr.]

seventy-five miles from its source, and found it composed of

Siliceous gravel	32
Calcareous gravel	11
Silica	10
Carbonate of lime	19
Alumina	21
Vegetable remains	7

The analysis of a soil in Touraine, which produced excellent hemp, gave me of

Coarse gravel	49
Carbonate of lime	25
Silica	16
Alumina	10

From the results of these analyses we find, that in the best earths there is a large proportion of gravel, which renders the soil light and easily worked, and facilitates the passing off of superabundant rains. In consulting the analysis of less fertile soils, we find that their fertility diminishes in proportion as one or the other of the three principal earths predominates; and becomes almost nothing in those which possess the properties of but one. The mixture of earths then is necessary to the formation of a productive soil; and their proportion can be varied only according to the nature of the climate, and the kind of plant to be cultivated. Siliceous and calcareous earths may form a larger proportion of the soil in moist, than in dry countries, and alumina may, in its turn, predominate in those lands, which, from their declivity, suffer the water to flow off freely; but a mixture of the three earths can alone form a good soil, and too great a disparity in their proportions materially affects the character of it.

The constituent parts of a soil have a constant tendency to become pulverized, and at length, by frequent tilling, by the action of salts, manures, and frosts, they are reduced to so fine a powder, as to cease to be productive. Rain falling upon ground in this state renders it perfect mud, which when exposed to heat becomes so hard, that the air cannot penetrate it, nor the tender fibres of plants force their way through it.

Davy has observed, that all soils composed of $\frac{19}{20}$ of impalpable matter are completely barren. The use of barn-yard manure will correct for a short time only this state of a soil, and it is better to mix with it the sand, and coarse gravel, which are necessary to restore it to fertility.

It appears that the three earths, which form the basis of the most fertile soil, enter into the composition of plants; Bergmann has proved this by analysis of several kinds of grain; and Ruckert by the results of his experiments upon a variety of vegetable productions, in a way to put it beyond doubt. About 100 parts of ashes well leached, and consequently disengaged of all their salts, yielded

	Silica.	Lime.	Alumina.
Ashes of wheat . . .	48	37	15
" of oats	68	26	6
" of barley . . .	69	16	15
" of rye	63	21	16
" of potatoes . .	4	66	30
" of red clover . .	37	33	30

All soils are not composed of the mixture of the three most important earths; some of them are formed by the union of two, as of silica with alumina, or of carbonate of lime with alumina, &c., and we occasionally find each one of them combined separately with quartzeous or calcareous gravel, forming land which may be cultivated.

It is seldom that the soils of which we have spoken in the preceding paragraph, are composed solely of the two substances referred to; but these so far exceed in importance all the others which enter into the mixture, as to give a character to the whole, which the latter cannot much affect.

The mixture of silex with alumina forms that soil called clayey, argillaceous, or simply *clay*. The properties of the alumina predominate in all clayey soils, which are less fertile in proportion to the increased quantity of it which they contain; when it equals or exceeds one half, they are only fit to be employed as the basis of some kinds of earthen ware; especially if the other moiety consist of silex finely pulverized.

I have had occasion to analyze three specimens of clay taken from three fields situated upon a plain, formed almost wholly of argillaceous marl; the first afforded

Silex in grains	17
Alumina	47
Silica	21

Carbonate of lime	10
Carbonate of magnesia	3
Oxide of iron	2

The second

Silex in grains	22
Silica	15
Alumina	45
Carbonate of lime	11
Carbonate of magnesia	4
Oxide of iron	3

The third

Silex in grains	19
Silica	24
Alumina	40
Carbonate of lime	9
Carbonate of magnesia	5
Oxide of iron	3

The other principles were the remains of manures part y decomposed. These three portions of soil were from land which produced but little. The water which stands upon clayey soils is always turbid and whitish, especially when agitated by the winds; heat has the effect of chapping and splitting these soils, and hardens them so, as to render them nearly impenetrable to the plough; in order to give them fertility it is necessary to employ a great deal of undecomposed barn-yard manure and litter; and it is advisable to sow, in the spring, crops of buck-wheat.

The soils which are formed of the waste, or from the decomposition, of mountains of calcareous free-stone, or of the carbonate of lime, whether primitive or secondary, frequently present only a mixture of calcareous sand, of which the grains are united by a carbonate of the same nature. These earths are in general light, porous, and well suited to many kinds of cultivation, especially in rainy climates, provided the bed be of sufficient depth, and formed upon a basis of rock, to enable it to retain the quantity of water required by the wants of vegetation; they are well adapted to the cultivation of the vine, and of sainfoin; and when they can be well manured will produce good crops of rye, oats, and barley. These soils have received the name of calcareous, though they almost always contain other principles, because the properties of the carbonate of lime predominate so much over those of the other substances, that the latter are hardly perceived.

The mixture of alumina and lime constitutes another species of soil, which by itself is but little productive, especially if alumina constitutes more than one half of it; but it is used with great advantage in improving some other kinds of land. The soil formed from this mixture is called marl, or a marly soil; the nature of it varies much, according to the difference in the proportions of its constituent principles; it is called clayey, or fat, when the qualities of alumina predominate in it, and calcareous, or poor, when the calcareous sub-carbonate gives it its character. Marl often contains shells, whole beds of it being sometimes formed almost entirely of their ruins; the "*fahluns*" * are of this species; this is the poorest kind, and the most suitable for improving argillaceous soils. The fat marl is often mingled with siliceous sand, which serves to enhance its value when used in amending light and calcareous earths. I have seen marl containing $\frac{70}{100}$ of sand, $\frac{20}{100}$ of alumina, and $\frac{10}{100}$ of carbonate of lime, used with advantage upon soils purely calcareous.

Marl is usually found in beds, buried at a slight depth in the earth; when taken out and exposed to the air it presents appearances which vary according to its quality. Under the combined influence of air and water, it is generally reduced to powder; but the decomposition is much more speedy and complete, when the two earths are in their proper proportions, than when either of them predominates.

The action of water dissolves, and carries off the alumina gradually, the carbonic acid of the atmosphere combines with the lime, which remains unsaturated, whilst the oxygen acts upon the iron, increasing its oxidation, till an entire change is produced in the nature of the earth, which acquires properties before strangers to it; it becomes pulverulent, and it is in this state that it is used to fertilize other earths.

When marl is very argillaceous, it may be hardened by the action of fire, and it then becomes sonorous, like well baked potter's ware; when it is very calcareous, fire converts it into lime; and I have seen it in Cévennes forming an excellent mortar when combined with a sufficient quantity of sand.

There is an immense difference in the proportions in

[* Probably "muschelkalk," or variegated marls.—Tr.]

which the two earths combine to form marl. Numerous analyses have been made by me of the marls of the centre and south of France, and I have found them to contain from 10 to 60 per cent. of sub-carbonate of lime, from 15 to 50 of alumina, and from 15 to 66 of siliceous sand. Marl is often produced by the decomposition of silex or flint.

ARTICLE V.

Of the Properties of the different Earths.

As the several earths contained in the soils of which I have just spoken, do not all possess the same qualities, and are very differently affected by air, water, and heat, the most powerful agents of vegetation, the excellence of a soil depends upon its containing the right proportion of each species of earth; and that is supposed to be the best soil, in which the virtues of one portion of its constituent principles correct the faults or defects of the rest. In order to produce these mixtures, to supply the deficiencies of poor soils, and to be able to render them, by art, suitable to the production of some particular article of cultivation, it is necessary to know the particular properties of each kind of earth; and it is upon this subject that I shall now speak.

Siliceous earth, or silica, exists in all hard primitive rocks, and forms nearly the whole of quartzeous mountains. In order to obtain it in its greatest degree of purity, it is fused with six parts of potash; it is then dissolved in water, and separated from the alkali by muriatic acid; the solution is evaporated to dryness, and the residuum washed in water affords pure silica. In this state silica has the appearance of a white impalpable earth, rough to the touch; when thrown into water it sinks with extreme rapidity, but its particles have no tendency to unite into one mass. The weight of silica compared to that of water is 2.5 to 1.*

[* Silica exists pure in rock crystal, and nearly pure in flint. It may be obtained pure by heating rock crystal to redness, quenching it in water, and reducing it to a fine powder. Fuse 1 part of this

The only acid which has been found to act upon silica is the fluoric, and this will disengage it from glass, of which it is one of the constituents. Hot alkaline lixivia act slightly upon it. It is found abundantly in plants, where it could only be introduced in a state of extreme division, or by being dissolved in some alkali.

This earth undergoes no change from the action of fire or air, because it is saturated with oxygen; according to the analysis of Davy and Berzelius, it is composed of equal parts of oxygen, and of a basis called *silicium.*

According to my experiments, this earth, though dry and impalpable, absorbs scarcely $\frac{1}{4}$ of its own weight of water, and permits it to escape by evaporation in $\frac{1}{3}$ of the time in which carbonate of lime, equally divided, parts with it; and in $\frac{1}{5}$ of the time, in which it escapes from alumina in the same state.

All the compound primitive rocks contain alumina; in order to obtain this pure, it must be precipitated, by the carbonate of ammonia, from a solution of alum, of which it forms the basis; the precipitate must be washed, and ignited, and the residuum is perfectly pure alumina; it is always in the form of a white powder, and possesses the following characteristics.

It is very astringent.*

Its specific gravity is from 2.2 to 2.3.

It is hardened by fire, and undergoes, by the action of it, a change which destroys its solubility in water.

It absorbs water with great avidity, not being saturated with less than 2.5 of its own weight, and retains it very forcibly, especially when that which softened its surface is evaporated; yielding it entirely only at a temperature sufficiently high to produce fusion.

Alumina saturated with water forms a soft paste, smooth to the touch, easily moulded, and receiving without difficulty any form which one may wish to give it.

According to the analysis of Berzelius, alumina consists of 46.70 of oxygen, and 53.30 of *aluminum.*

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powder with 3 of potassa in a silver crucible, and evaporate to dryness. Wash the mass in boiling distilled water, upon a filter, and the white substance which remains is pure silica.† Its color is white; its specific gravity 2.66.—Tr.]

[* Brande (*Manual of Chymistry*) says it is *tasteless.*—Tr.]

[† This is the usual process, but the silica always retains potassa, and the earth obtained by simply reducing the colorless rock crystal to powder is more pure. (Brande's *Manual of Chymistry*, p. 235.)—Tr.]

Lime is found in nearly all primitive rocks, and forms the basis of all calcareous mountains, whether primitive or secondary.

It is obtained pure by calcining, at a high temperature, Iceland spar, primitive marble, etc., or by precipitation from a solution of them in an acid. Its taste is acrid and caustic. It absorbs water with avidity, and with a hissing noise, and forms with it a hydrate, or a paste which is the basis of mortars. Carbonic acid, for which it has a strong affinity, combines with it, separating it gradually from the water, which evaporates. Pure lime is composed of 28.09 of oxygen, and 71.91 of *calcium*.

The lime which is found in lands appropriated to agriculture, is in the state of a carbonate, and possesses characteristics very different from those of its pure state. Its specific gravity is 2.0. The pulverized carbonate absorbs 0.8 of its own weight of water, and retains it less forcibly than alumina does.

The mixture of these earths has the general character which results from the union of the qualities, which each earth brings into the composition of the soil; but independently of the action which these principles exercise upon each other, air, water, labor, and the use of manure, produce modifications of the soil which it is important for us to understand.

It is my intention to examine the influence which all these agents exercise over the various soils, and I enter upon the discussion with the more interest, because it furnishes to the agriculturist reasons for the methods he has pursued; and explains to him many phenomena which he has observed, but for which he could not account.

We have already seen that the atmosphere furnishes to plants two of their constituent principles; of which one (carbonic acid) contributes to their support by the carbon which it deposits in them, whilst the other (oxygen) takes from them a portion of carbon; this last becomes again the principal agent in the decomposition of manures and dead vegetables; but the action of air is not confined to the performance of these offices, however important they may be.

The air may be considered as a vehicle constantly loaded with a quantity of water in vapor, of which the coolness of the night causes it to deposit a part upon the earth. The surface of the ground and the leaves of plants are often moist in the morning; the return of the sun and the heat of the day evaporate this liquid, to be deposited again at sunset, and during the night; thus by an alternate movement, determined by the changes in the temperature of the atmosphere at different periods of the twenty-four hours, water is constantly applied to plants, to preserve them from the excess of heat, which would wither, and dry up their organs.

The aqueous vapors suspended in the air begin to be condensed and precipitated at sunset, and with them is deposited the greatest part of the emanations which have arisen from the earth during the day; these exhalations, though beneficial to vegetation, are almost always injurious to man, and it is not without reason that he fears and shuns the night damps. In southern climates, where the heat of the sun is more intense, and rains less frequent than in northern, vegetation is supported by the dews, which are very abundant. In order that the dews of night may produce their best effects upon vegetation, it is necessary that the soil should unite certain qualities, which it does not always possess.

When the soil is hard and compact, and forms by the action of the air an impenetrable crust, the dew is deposited upon its surface, and evaporated by the rays of the sun, without having moistened the roots of the plants, or softened the earth around them; so that, of the organs that serve to convey nourishment to the plants, the leaves are the only ones benefited by the dew, while the roots, which are the principal vehicles of nutriment when the plant is fully developed, are not in any degree benefited by it. It is necessary, in such cases, that the soil should be softened, lightened, and divided, so that the air may convey the water with which it is charged, to the roots of the plants, and to every part of the earth surrounding them, to a certain depth; then the plant can imbibe, through all its pores, the reviving moisture; and that which is received by its roots is more lasting than that which it absorbs in any other way, because the roots being sheltered from the direct rays of the sun, evaporation takes place less rapidly, and the moisture is retained, whilst the leaves are speedily dried by the heat. Besides, that earth which is most easily affected by the dews, yields most readily to the action of roots, whether it be to fix the plant firmly by their extension, or to draw from the soil its nutritive properties.

This explains in a natural manner the origin of a custom observed by all agriculturists, and of which all acknowledge the advantage. When vegetables, such as peas, beans, potatoes, and other roots are sowed in furrows at equal distances from each other, the soil in the intervals is hoed, or dug, with the utmost care, and thus rendered light, soft, and permeable to the air, whilst at the same time weeds, which would be hurtful to the cultivated plant by depriving them of nourishment afforded by the ground, are destroyed; and the soil rendered more fit to receive the rain, and convey it to the roots. I do not deny that these benefits are real, but I hold them to be secondary, and subordinate to the advantage derived from opening access to the air, and permitting it to deposit its dews upon the roots, and upon the earth in contact with them.

I have uniformly observed the effect of this method to be equally speedy and favorable in the cultivation of beet roots, and I have never employed any other, to restore their vegetation to its freshness when it becomes yellowish, and drooping; in three or four hours it will become of a beautiful green, and the leaves spread themselves out, although no rain may have fallen; and this often when the soil had not contained a single weed. I have observed the same effect produced upon the other culinary roots.

A custom which is universally practised in the south of France, attracted my attention for a long time, without my being able to account for it. In that country, where it hardly ever rains during the summer, the foot of each setting of the vine is laid bare by digging around it a circular trench, deep, and wide enough to contain uncovered the stump, and the radicles proceeding from it; and the opening is speedily covered over by the leaves and branches. It is evident that this method has no other advantage than that of facilitating the access of the air to the roots, that it may deposit there the dew with which it is more abundantly charged than in cold climates; if it were not thus, this practice would expose the vines to be dried up by the scorching heat of the sun.

All soils have not the same affinity for water, which arises from their different degrees of tenuity, or the division of their particles, and from the nature of the substances which enter into their composition. In general, the more finely the parts of a soil are divided, the better they absorb water

The absorbing powers possessed by the elements composing a fertile soil, may be arranged in the following order.

Vegetable substances.
Animal substances.
Alumina.
Carbonate of lime.
Silica.

Alumina, and those soils where its characteristics predominate, do not receive the moisture from the atmosphere to the greatest advantage; they retain the water, which they imbibe, with so much force, that the plants produced upon them suffer as much from drought as if they grew in sand.

The light porous earths, composed of sand, carbonate of lime, silica, and decomposed animal and vegetable substances, in just proportions, are the best for absorbing and retaining moisture, in order to transmit it, with regularity and beneficial effect, to the plant.

The experiments conducted by Davy have produced results of great importance to agriculture; he has compared the energy with which various soils absorb humidity from the atmosphere, and has uniformly found, that the most fertile possessed this power in the highest degree; so much so, that the fertility of soils might be estimated, and classed according to it.

1,000 parts of a celebrated soil from Ormiston, in East-Lothian, which contained more than half its weight of finely divided matter, of which 11 parts were carbonate of lime, and nine parts vegetable matter, when dried at a temperature of 212° Fahr., gained in an hour by exposure to an atmosphere saturated with moisture at a temperature of 62°, 18 grs. in weight.

1,000 parts of a very fertile soil, formed by the deposits of the river Parret, in Somersetshire, gained 16 grs.

1,000 parts of a soil from Mersey, in Essex gained 13 grs.

1,000 grains of a fine sand from Essex gained 11 grs.

1,000 grains of a coarse sand gained only 8 grs.

1,000 grains of the soil from Bagshot-heath gained but 3 grs.

The absorbing power of a soil has always been found to be in proportion to its fertility, and to the excellence of its situation.

It is of the utmost importance in the science of agriculture, that the comparative powers of the various soils for absorbing atmospheric moisture, and the degrees of force with which they retain it, should be ascertained. The means necessary to be employed in ascertaining these capacities of soils, are in the power of every cultivator; he has only to dry thoroughly the same weight of each soil in a state of equal division, and to weigh them night and morning for several days, and he will be able to form an estimate of the quantity of moisture which each has imbibed during the night. In order to obtain these results with exactness, it is necessary that the assays should be made upon equal weights of earth, in an equal state of division, equally dried, and spread in layers of an equal degree of thickness.

From the statements which I have made, it is easy to be perceived, that air and water are two powerful agents in promoting vegetation; they act upon it directly, by furnishing from their own decomposition nutritive principles; and they act as auxiliaries, by serving as vehicles for the conveyance into the organs of plants of such substances as are necessary for their support.

But though the plant is furnished with aliment through these agents, it is heat alone, that, by animating the vegetable organs, enables it to elaborate within itself the nourishment which it receives. The effect of temperature is perceptible not only in plants, but in many classes of animals; nearly all insects are benumbed by the cold, and reanimated by the heat.

All soils are not equally capable of receiving and retaining heat. The white earths are warmed with difficulty; when pipe clay or aluminous marl predominates in a soil, it is nearly always damp, and retains but little heat. White chalky soils require much heat to warm them; but they part with their heat less quickly than the first, whilst colored earths absorb heat, in proportion as the depth of their hue increases from brown to black.

Davy has remarked that a black soil containing nearly $\frac{1}{4}$ of vegetable matter, when exposed to the sun, acquired in one hour an elevation of temperature which raised the thermometer from 65° to 88°, whilst under the same circumstances, a soil whose basis was chalk, raised it only to 69 degrees. When the black earth was carried into the shade at the temperature of 62°, the thermometer fell

15° in half an hour, and the chalky earth lost by the same exposure 4°.

Equal quantities of fertile brown soil, and of sterile clay, were dried; and their temperature raised to 88°; upon being then exposed to air at the temperature of 57°, the brown soil lost, in the space of half an hour, 9°, and the clay 6°; moistened clay at 88°, exposed to a temperature of 55°, fell to the same in less than a quarter of an hour.*

The variations of temperature in soils of different natures, with their several degrees of affinity for heat, and of power for retaining it, deserve the attention of the agriculturist. The only instrument necessary for conducting experiments upon this subject, is a good thermometer; and by the aid of that we can ascertain the kind of soil suited to any one species of plant, since all do not require the same intensity, nor the same continuance of heat.

The different degrees of heat which earths imbibe at the same temperature is known to most agriculturists, and many of them turn the knowledge to advantage. It is customary with those who cultivate the table lands upon the sides of the Alps, to throw black earth upon the snow, in order to hasten its thawing, that they may commence their cultivation as soon as the sun returns to them. The same means are employed in green-houses and orangeries; the walls are blackened, and the soot spread over the soil serves to concentrate and fix the heat, to such a degree, that in the month of July, upon the Cramont, at an elevation of 9077 feet, where the temperature was at 43°, M. Saussure found that a thermometer which was placed in a box lined with blackened cork, and of which the opening was closed by three glasses placed at some distance from each other, rose in two hours from 38° 75′ to 99° 50′.

Independently of the heat which the atmosphere communicates to the soil, and of the modifications wrought upon it by the color of the constituent principles, it is in the power of art to lessen or to increase the temperature of lands at will. Animal manures develope more or less heat, according to their nature, and their state of fermentation; those which have not been decomposed, excite more heat, and maintain it for a longer time, than others.

[* See Davy, p. 179, 180. Chaptal has reduced his degrees erroneously, and they are corrected as above from Davy's *Agricultural Chemistry*.—Tr.]

The excrement of the sheep and horse is more heating in its action than that of cows; the black or brown manures warm the soil more than marl or chalk.

ARTICLE VI.

Of the Properties of Mixed Earths, and the Methods of rendering them capable of a good Cultivation.

I BELIEVE that I have sufficiently explained the origin of soils, their composition, and their influence upon vegetation; whether it be exerted through their constituent principles, or by the effects which are produced upon them by air, heat, &c.; it now remains for me to speak of some circumstances which modify soils, and with which the agriculturist ought to be acquainted.

I have repeated several times in this chapter, and in that in which I have spoken of manures, that the results of the decomposition of animal and vegetable substances, concur with the constituent principles of air and water to form the food of plants; I have remarked, that plants being immovable, it was necessary that these supplies should be presented to them, and in a state which would admit of their being readily absorbed by the fibres of the plants; to these observations I have added, that heat animates plants, and gives to their organs the power of decomposing these substances, and, from the elaboration of them, of forming all the products of vegetation.

In order that plants should derive the greatest advantage from their means of support, it is necessary, that their nourishment should be supplied to them in proportion to their wants, and consequently, that the decomposition which the greatest part of these aliments must undergo, should neither be too speedy nor too moderate; the soil appears to be the principal agent in producing these modifications, and serves to regulate the others; it forms a magazine, in which are deposited nearly all the aliments of plants, and it ought to possess all the properties requisite for supplying the wants of vegetation.

The characteristics which mark each one of the earths which constitute a soil, concur by their union to produce this effect; chalk and silica retain but little water, but their mixture with alumina preserves plants from suffering so often from drought; without the presence of alumina, they would be alternately inundated, and dried up. Clay alone does not permit the roots of plants to extend themselves, nor allow the air to penetrate to them; but mixed with silica, carbonate of lime, and sand, it forms a porous soil, which possesses these properties. Chalk preserves animal and vegetable substances from a too rapid decomposition. Alumina and the oils combined together produce a saponaceous mixture, which can be imbibed by plants, and thus furnishes them with two principles, which separately are insoluble in water.

The composition of soils varies according to the difference in climate, otherwise their fertility would be lessened. The quantity of rain that falls is so various, that even within the extent of France, it ranges, according to situation, from twenty to thirty, and according to Giobert, at Turin, to thirty-four inches. There are some countries where the atmosphere is almost always cloudy, and the air laden with moisture; whilst there are others in which the sun is not obscured for six months together. It is evident that in those countries where the air is uniformly damp, and in those where rain is abundant, the soil may be, without inconvenience, more calcareous than argillaceous; and that the best soils in the two divisions would differ very widely as to the proportions in which their several earths would be combined.

Soils should vary according to the nature of the plants to be cultivated in them; some prefer a porous, dry, and arid soil, others flourish only in land constantly moist; there are some that require a great degree of heat, others vegetate in the midst of snows. These peculiar tastes of plants ought to be known to the agriculturist, that he may select for each one the soil best adapted to it; or change the characters of those he possesses, so as to afford to each plant the soil most congenial to it.

In order that a plant should flourish in a soil, it is not always sufficient that the earths composing it are of the right kind, or suitably proportioned; it is necessary to unite other circumstances which are not always to be met with; for example, the arable soils which are based upon rocks, vary considerably in depth; and the thickness of the bed not only exerts an influence upon the powers of vegetation, but determines the kind of plant which can be cultivated upon it. The bed of earth ought to be from 10 to 12 inches in depth for grain, and much more than that for clover and sainfoin; for trees it must be much deeper than for these, otherwise their roots, running but little below the surface of the ground, will extend their shoots to a great distance, and thus exhaust the strength of a large portion of soil. Trees are often found upon the sides of mountains, which are almost entirely devoid of a covering of earth, but in this case the chinks and crevices of the rocks supply the place of earth, or rather the rocks are of so spongy and porous a nature, as to permit the roots to penetrate them. In the Cévennes and Limousin the most beautiful chestnuts are planted upon granite and free-stone; and the famous vines of the Hermitage prosper in a soil of granite decomposed at the surface.

It is not immaterial of what substance the sub-stratum of the beds of earth are composed; if it be of sand, the soil above will dry more quickly than if it were of marl or clay. A bed of clay under one of sand contributes to its fertility by retaining the water, which easily filters through the last, and thus preserving its humidity; but if the water collected upon the clay moisten for too long a time the roots of the plants, they become languishing. I have always observed that roots might be exposed to living and flowing water, without being injured by it, but that stagnant water is always hurtful, and, for the most part, destructive to them. Agriculturists have learned this by experience, and hence has arisen the custom of draining their fields and meadows. In lands which are too moist, a good effect is produced by forming beds of flints, or pebbles, upon which a layer of mould may be placed; I have seen excellent meadows made in this way, upon land which had never before produced any thing but rushes.

A clayey or marly soil, which lies upon a bed of calcareous and porous rock, is more fertile than one which rests upon a foundation of hard rock, impermeable to water; the reason of this is very simple; in the first case, the water filters through the rock, and escapes; in the second it remains stagnant, rendering pasty a soil possessing none of the requisites for vegetation.

The situation of land causes a great variety in its fertility, and in the nature of its productions; lands which have a southern exposure dry more quickly than those lying towards the north, but vegetation is more active in the first than in the last, and the quality of their productions superior.

The slope of lands likewise affects their fertility; a piece of ground which lies upon a declivity, loses water more readily than one which is horizontal, and vegetation is less strong upon it, but the productions are of a better quality. There is a vast difference between wines made from the same kind of grape, raised in the same soil, if one be the production of the harvest upon the declivity of a hill, and the other of the plain at its foot.

Inclined lands, where the slope is rapid, and the soil light and porous, are liable to the evil of having the manures, applied to them, carried off by heavy rains; even the soil sometimes experiences the same fate, and the surface becomes furrowed, by ravines laying bare the rocky foundation. This frequently happens to lands cultivated upon the sides of mountains, till they become at length completely barren; and hence we must conclude that it is unwise to clear up the declivities of mountains, since a temporary advantage reduces the land to a long period of sterility.

Soils composed of the same earthy principles, combined in the same proportions, will still present very different results, according to the nature and quantity of the salts which they contain. I have made known those which are usually found in plants, and which for this reason must be regarded as suited to vegetation; but their proportions are limited, and if they are too abundant, they become hurtful. The salts cannot be regarded as the actual food of plants; they are only auxiliaries, though very powerful ones, to their nutrition. The organs of vegetables require exciting; and heat and the salts act upon them as stimulants. The salts are to plants what spices and marine salts are to man. Independently of their stimulating powers, the salts exert a chymical action upon the aliments of plants, by combining with them, rendering some of them soluble in water, and moderating the decomposition of others; and thus contributing to regulate and facilitate the process of nutrition.

Even from the part which the salts perform, it is evident that they ought to be supplied only in suitable proportions; if they are too abundant, or very soluble in water, they will be absorbed by the organs of the plants in such a quantity as to produce irritation and dryness. Thus the best soil may be stricken with barrenness if the salts become too abundant in it.

Thorough ploughing contributes largely to the fertility of lands; but in order that it may produce its best effects, it is necessary to have regard to some circumstances which are generally but too little attended to.

Ploughing divides and softens the soil, mixes thoroughly its constituent principles, destroys weeds, and disposes them to decay; and frees the ground from those insects which often abound in it.

The ploughings should be more numerous, and conducted with more care, upon a heavy soil, than upon one which is light and porous. Clayey soils should be ploughed only when dry; when they have imbibed water they form a soft paste, on which ploughing has no other effect than to trace furrows in the mud. Sandy and calcareous lands may be ploughed at all times. Deep ploughings are very advantageous to lands which are of the same nature to a considerable depth, since, in addition to the good effects arising from the operation itself, those parts of the soil which have become impregnated with the manures, that the rains have carried down below the surface, are thrown up to contribute to the nourishment of vegetation. Deep ploughings are likewise useful in those lands where the upper layer, being of too clayey and compact a nature, rests upon a bed of sand or carbonate of lime, which by this operation is brought to the surface and mingled with the upper layer, thus rendering it more fertile than it could be made by any other means. An equally good result is obtained from deep ploughing in the reverse case, that is, when a soil, too sandy or calcareous, rests upon an argillaceous bed.

But deep tillage does not belong to all soils, nor is it of use under all circumstances. For instance, if a soil is situated upon a vein of earth charged with black oxide of iron, or upon a bed of marl, the mixture which would be produced by deep tillage would reduce the land to almost entire sterility for two or three years. I have myself experienced this result, and I speak from personal knowledge. Near a forest of oaks upon one of my estates, the land, which had been cultivated, was of an argillaceous character for about six inches in depth; under this lay a bed of very dark brown earth, of five or six inches in thickness, and composed of silex, clay, and oxide of iron.

I caused the two beds to be broken up and mixed well together with the spade. The first year the harvest from it was almost nothing, much less than before, though it had never been fertile. The second year it was a little more productive; but it was not till the fifth year that it recovered its usual degree of fertility. One of my friends possessed a piece of ground of a moderate degree of productiveness. The soil, which was sandy and very dry, was much improved by the application of marl, which he allowed to decompose upon it for two years before cultivation. As the same person had a bed of marl in one of his fields at the depth of a foot, I advised him to break up a piece of it, twelve or fourteen yards square, and to mix the marl with the upper layer of earth, in a proportion more considerable than in the other case. The portion of the field thus operated upon was nearly barren for two years, after which it was more decidedly fertile than before.

These two cases struck me very strongly. I sought for the reason of the changes, and believe that I have found it in the nature of the inferior layer of the earth at the time of being mixed with the upper soil.

In the first case the oxide of iron, which colored the bed brown, was at the lowest state of oxydation; but at the moment that it was brought into contact with the atmospheric air, it began to combine with new portions of oxygen, and the earth could not become fertile till the iron was saturated. The progress of oxydation entirely changed the color of the soil; from black it became of a deep lively yellow. This fact may admit of a different explanation. Is the oxide of iron, in its black state, destructive to vegetation? Does that oxide, which, by attracting the oxygen from the atmosphere, decomposes it, destroy by its action the necessary and salutary influence of that fluid upon plants? These are questions which can only be answered by a long experience.

In the second case the cause of sterility was different, though it had a general relation to that of the first. Marl is principally composed of sub-carbonate of lime and alumina; the proportions in which these are combined constitute all its varieties. The lime contained in marl, as it is taken from the bed, is never saturated with carbonic acid; but after being exposed to the air, it becomes at length saturated with the acid it receives from it, crumbles, and effloresces. The decomposition of marl may be hastened by frequently turning it, so as to allow the air free access to the lime; and this method is generally practised by those who employ marl as a manure. The same questions may be proposed in regard to imperfectly carbonated lime, as to the oxide of iron.

When M. Fellenberg wished to verify his principles of cultivation upon his estate of Hofwyl, he had his land broken up to the depth of three or four feet, and it produced nothing till the end of two or three years.

These facts, and many others which I could cite, prove that it is necessary for earths, in order to possess great fertilizing powers, to be saturated with all the principles which they can imbibe from the atmosphere. Thus those which, by the depths of their beds, have been constantly secluded from the action of the air, will require to be exposed to it a long time before becoming fertile. Those who are engaged in agriculture know this fact, and express it by saying that the air deposits its fructifying principles upon the earth. They use the expressions,—"The soil is not made enough; is not ripe enough; is not aired enough," &c. This understanding of the subject is not very exact, but sufficiently so to direct their practice.

When, by digging or deep ploughing, the mould has been mixed with these unsaturated earths, it ought to be stirred at long intervals by the plough or pick-axe, before being sowed. By presenting all the parts successively to the action of air and water, they are enabled to imbibe from them those principles in which they are deficient; and thus the same effect is produced upon them, as is wrought upon marl or the black ferruginous earths by a longer exposure, after they have been taken from their beds.

ARTICLE VII.

Of the Analysis of Arable Soils.

Though experience and long observation may enable an agriculturist to become acquainted with the nature and degree of fertility of each part of his land, it will in most cases be convenient for him to acquire this knowledge by shorter and more direct methods.

I shall not point out the process of an analysis with the most minute exactness; this would place it beyond the skill of the greater part of agriculturists to perform; and the precision of the results would be useless for the purpose which I have in view. I shall limit myself to describing the steps which ought to be taken for ascertaining the nature of the principal substances, whether earthy, saline, metallic, vegetable, or animal, which enter into the composition of a soil, whilst it is necessary to insist only upon those which concur most powerfully in rendering it fertile.

In analyzing an earth, a small quantity of it should be worked carefully by the hand before weighing it. The first operation consists in drying this specimen carefully, in order to know the weight of water it contains. For this purpose it is placed in a vessel over the fire, of which the heat must be just sufficient to evaporate the water. This temperature must be preserved from fourteen to twenty minutes. In order that no more heat than is necessary may be applied, it is customary to put a bit of wood at the bottom of the vessel, or a few bits of straw into the earth subjected to the experiment, and to withdraw it from the fire as soon as these begin to turn brown.

The next operation is to weigh the earth a second time; and the loss it has sustained will be equal to the weight of the water which has been evaporated. This operation does not determine exactly the weight of water contained in the earth, because one part of it is nearly solidified by its combination with some of the earthy principles, as alumina, the salts, and many other substances, animal and vegetable; but it ascertains the quantity which served to moisten the earth. In performing experiments upon earths at a high degree of temperature, it is easy to ascertain the power which they have of absorbing moisture, and from this some judgment may be formed of their fertility.

As soon as the quantity of free moisture contained in the earth is ascertained, the sample must be bruised in a mortar till it becomes only a collection of small particles. By means of shaking upon a sieve, the gravel and other hard substances, which enter into the composition, may be separated from the other matters, which, having been rendered finer, will pass through readily. The coarsest particles should be assayed separately from the others; if they are calcareous, acids will dissolve them, producing at the same time an effervescence; to prove this, a few grains of them may be put into a glass containing good vinegar, or muriatic acid diluted with three or four parts of water; if they are composed only of carbonate of lime, they will be entirely dissolved, especially if the liquor should still preserve its sharp and sour taste; for in all these experiments it is necessary to use an excess of acid.

If the coarse particles do not effervesce with an acid, they are composed entirely of silica or alumina. These are easily distinguished from each other, the silica being rough to the touch, scratching glass, and sinking quickly in water; whilst alumina is smooth and unctuous to the touch, and mixes with water, in which it remains some time suspended.

The coarse particles may be composed by the union of the calcareous, siliceous, and aluminous earths; but in this case the acids have dissolved a part of the calcareous particles; and, after removing the acid which holds them in solution, it is easy to ascertain by the abovementioned characteristics, whether the insoluble portion remaining in the glass be silica or alumina.

If the coarse particles are only of quartzeous sand or of pure silica, water and the acids will produce no effect upon them; and their nature can be easily determined by the characteristics I have given of silex and alumina.

It sometimes happens that these coarse particles are mixed with the remains of animal or vegetable substances imperfectly decomposed; but these will be easily recognized by the characteristics which distinguish fossil substances.

Nothing now remains to be done but to examine the finely divided and pulverulent soil, which passed through the sieve; this contains the earths, salts, and animal and vegetable substances, in a state of minute division. In order to ascertain the nature and proportions of the principles contained in this mixture, it must be first weighed, and then boiled in four times its weight of water, from ten to fifteen minutes; the whole should then be well stirred, and left to settle; a precipitate will soon be deposited, consisting only of the heaviest portions of the mass, usually of fine siliceous sand; the turbid liquor which floats above being thrown on a filter, the earths and some salts not easily soluble remain upon the filter, and the water charged with all the soluble portions flows into the vessel destined to receive it.

We find, by this operation, three distinct products; first, the precipitate deposited at the bottom of the vase in which the ebullition was performed, consisting of the finest sand; secondly, that remaining upon the filter, and which consists of a mixture of earths and insoluble salts; and, thirdly, that which contains in solution all the salts and animal and vegetable substances capable of being dissolved in boiling water. The two first, after they have been dried with care, and their weight ascertained, must be examined in order to know the nature and proportions of the substances which compose them.

I have previously observed, that the deposit constituting the first product, is generally composed only of silica; if otherwise, it could be tested by acids, which will dissolve all the calcareous portions of it, while those parts which are insoluble may be treated by the means, which I have already pointed out, for separating alumina from silica.

For the second part, which is the one remaining on the filter, it is sufficient to make an analysis of it, by pouring upon it muriatic acid diluted with four parts of water, till it will effervesce no longer; this will dissolve the carbonates of lime, and of magnesia, should there be any present, as well as any oxide of iron; the solution being filtered, any substance not dissolved will remain on the filter, and must be washed with water, till the water runs off tasteless; the residuum must be dried and weighed; it generally consists of alumina, and some animal and vegetable matter.

In order to ascertain if the muriatic acid has dissolved any oxide of iron, stir it with a bit of oak bark; if the liquor renders it brown or black, it contains iron; in order to ascertain the quantity, throw into the liquor prussiate of potash till it will no longer form a blue precipitate; let it settle; collect the deposit, and heat it to redness; that which remains after this operation is the oxide of iron, and must be carefully weighed.

When the solution has been freed from the oxide of iron, there remains in it only lime, and perhaps a little magnesia; these can be precipitated by means of a solution of carbonate of soda, which must be poured into the muriatic acid till a precipitate is no longer thrown down; after having poured off the liquor, the residuum must be washed and dried; when its weight will give the quantity of carbonate of lime contained in the earthy mixture.

If the carbonate of lime, and the other deposits obtained, be of a brown color, it is to be presumed, that they contain a mixture of animal or vegetable substance, of which the quality and proportions may be ascertained by throwing them upon a red-hot iron, and holding them over a fire of such a temperature, as will heat the iron to whiteness; if the smoke arising from them have the odor of burning leather, hair, or feathers, the substance contained in them is animal; but if it have the smell of wood smoke, it is vegetable. The two substances are sometimes combined, but the means of ascertaining in what proportions are beyond the skill of an agriculturist; I have therefore thought that I ought to confine myself to the experiment necessary for ascertaining their presence.

The method I have just described is easy, and in the power of any agriculturist, however little informed; it is not exact, but it furnishes results approximating near enough to the truth, to enable any one to ascertain the nature and proportions of the earthy substances which enter into the composition of a soil. A greater degree of precision in the analysis would require the employment of many agents unknown to the agriculturist, and a habit of analysis which he cannot be supposed to possess.

But as the salts play an important part in vegetation, and as all soils are in some degree impregnated with them, I believe I ought not to dispense with pointing out the means of recognising them, and for this purpose I shall be obliged to have recourse to some particular process.

By boiling the finely divided earth in water, we can separate from it all the soluble salts it contains, and the evaporation of the liquid, which holds them in solution, will enable us to know their natures and proportions. If the operation be carefully conducted, the salts can be obtained in crystals, and, by the character of these, their properties can be distinguished. Nitre has a sharp taste, and consumes upon glowing charcoal; marine salt decrepitates, and splits with a sparkling appearance over the fire; the sulphate of soda swells up with the heat, giving out an aqueous smoke, and leaving a dry white residuum. But when the salts are insoluble, as phosphate of lime; or soluble with difficulty, as sulphate of lime, water will not act upon them, and they remain mixed with the earth without their existence being suspected, as long as an analysis is confined to the limits I have laid down. However, these substances, especially the sulphate of lime, influence so much the quality of soils, that it is necessary to furnish the means for ascertaining their existence. I will however observe, that these salts are contained in the earths in so small a quantity, as not to influence sensibly the results of the analysis I have directed, for ascertaining the natures and proportions of the other principles which essentially compose them.

To ascertain if a soil contains sulphate of lime, (gypsum, plaster of Paris,) take an exact quantity, four hundred grains for example, mixed with one third the quantity of powdered charcoal, expose it in a crucible during half an hour to a red heat; afterwards boil it for a quarter of an hour in half a pint of water, filter the liquor, and expose it for some days in an open vessel; if it form a white precipitate, the soil contains sulphate of lime, and the weight of the deposit will make known nearly the proportion. (Davy.)

To judge of the existence of phosphate of lime, digest the earth in an excess of muriatic acid, evaporate the solution to dryness, wash the residuum in a large quantity of water, and the insoluble phosphate will remain alone.

CHAPTER III

OF THE NATURE AND ACTION OF MANURES.

Under the general head of manures are comprehended all those substances which, existing in the atmosphere or combining with the soil, can be drawn in by the organs of plants, and contribute to the progress of vegetation.

Manures are furnished by various bodies belonging to the three kingdoms of nature. Those most commonly employed are the results of decomposed vegetable substances, and some animal matters.

The salts, which likewise serve for manures, are imbibed by the pores of plants, and serve to stimulate vegetation.

By comprehending all these substances under the generic name of manures, too extensive a signification is given to the word. I divide manures into two classes; and in order to deviate as little as possible from the customary mode of expression, I shall call those nutritive manures, which supply plants with nourishment, and all those which excite the organs of digestion stimulating manures. These last are, strictly speaking, the seasoning; the spices, rather than the food.

ARTICLE I.

Of Nutritive Manures.

The nutritive manures are those which contain juices or other substances, which, being dissolved in water, or otherwise divided to the most minute degree, are capable of being drawn into the organs of plants. All the vegetable and animal juices are of this description.

These substances are rarely employed in their natural state for the aliment of plants. It is generally considered preferable to allow them to putrify or ferment; the reason of this is simple. Besides the decomposition resulting from this operation, which renders the substances more soluble in water, the gases produced by it, such as the carbonic acid, the carburetted hydrogen, azote, and ammonia, furnish food for plants, or stimulants for their organs of digestion. It is not, however, well to prolong this decomposition too far; for if it be completed, there will remain only some fixed salts, mixed with those earths and juices which have resisted its action. Besides, the effect of manures, which have been entirely decomposed, is almost momentary, lasting but for a single season; whilst those which are employed before arriving at this state, continue to exert an influence for several years. In this last case, the decomposition, retarded by the separation of the manures into small portions, continues to go on gradually in the earth, and thus furnishes vegetation with its necessary aliments for a long time.

The excrements of animals, formed by the digestion of their food, have already undergone a decomposition which has disorganized the principles of their aliments, and in a greater or less degree changed their nature. The strength of the digestive organs, which varies in each species of animal, the difference of food, and the mixture of the digestive fluids furnished by the stomach, modify these manures to a very considerable extent.

The excrements of some animals, as of pigeons, fowls, &c., are employed without undergoing any new fermentation, because they consist mostly of salts, and contain but few juices. Fields are often manured with the excrements of sheep, collected in the sheep-folds, or scattered, as in parks, by the animals themselves upon the soil ; but in general the dung of horses and of horned cattle is made to undergo a new fermentation before being applied as manure.

The most general method of producing the fermentation of the dung of quadrupeds, is, in the first place, to form upon the ground of sheep-folds and stables a bed of straw or dry leaves. This bed is covered with the solid excrements of the quadrupeds, and impregnated with their urine. At the end of fifteen days or a month, it is carried to a place suited for fermentation, and there formed anew, care being taken every day to spread upon it litter and the scatterings of the racks. The formation of these beds, contributes much to the healthfulness of the stables and to the cleanliness of the animals. When, from a scarcity of straw, the beds cannot be made of sufficient thickness, or renewed often enough, a layer may be formed of lime or gravel, broken fine and covered with straw. These earths will imbibe the urine, and when they are penetrated by it may be carried into the fields to be buried in the soil. The nature of the earth, upon which beds are formed in sheep-folds or stables, should vary according to the character of the soil which is to receive them, because, by attention to this, the soil may be improved as well as manured. For argillaceous and compact earths, the layers should be formed of gravel and the remains of old lime mortars ; whilst those of fat marl or of clayey mud should be reserved for light and dry soils.

In some countries, where good husbandry is much attended to, the floors of the stables are paved and slightly sloping, so that the urine flows off into a reservoir, where it is fermented with animal and vegetable substances, and used to water the fields at the moment when vegetation begins to be developed.

The art of fermenting dungs with litter is still very incomplete in some parts of France. In one place they let it decay till the straw is completely decomposed; in another they carry it into the fields as soon as it is taken from the stables. These two methods are equally faulty. By the first, nearly all the gases and nutritive juices are dissipated and lost; by the second, fermentation, which can take place only in masses, will be but very imperfectly carried on in the fields, and the rains can convey to the plants only that portion of the nourishment afforded by the manure, which they can obtain by a simple washing.

The most useful art perhaps in agriculture, and that which requires the most care, is the preparation of dung-heaps. It requires the application of certain chymical principles, which it is not necessary for me to explain, since it is sufficient to point out to the agriculturist the rules by which he should be governed in his proceedings, without requiring of him an extensive knowledge of the theory upon which they are founded.

Solid substances, whether animal, vegetable, or mineral, do not enter into plants unless they are previously dissolved in water, or are drawn in with that fluid in a state of extreme division.

Animal and vegetable substances which are by their nature insoluble in water, may, by being decomposed, form new soluble compounds, capable of furnishing nourishment for plants.

Animal and vegetable substances deprived by the action of water of their soluble particles, may, in the course of their decomposition, form new compounds susceptible of being dissolved. Of this I have given instances in speaking of mould.

That which renders the art of employing dung-heaps difficult, in proportion as it is useful, is, that some methods which are adopted occasion the loss of a part of the manure. In fact, when the clearings of the farm-yard are carried fresh into the fields, and applied immediately to the soil, vegetation is undoubtedly benefited by the salts and the juices contained in them; but the fibres, the fatness, the oils, remain inactive in the earth; and their final decomposition is slow and imperfect. If, on the contrary, the collections of the farm-yard be heaped up in a corner of it, the mass will speedily become heated, carbonic acid gas will be evolved, and afterwards carburetted hydrogen, ammonia, azote, &c. A brown liquid, of which the color deepens gradually almost to black, moistens the heap, and flows upon the ground around it; all is by degrees disorganized; and when the fermentation is completed, there remains only a residue composed of earthy and saline substances, mixed with a portion of blackened fibre, and some carbon in powder.

In those places where they do not allow fermentation to arrive to this degree of decomposition, they still lose, by mismanagement, a considerable part of their manure.

The most common method is, to deposit in a corner of the farm-yard the dung and litter, as it is drawn from the stables, adding to the mass every time these are cleared, and allowing it to ferment till the period of sowing arrives, whether it be in spring or autumn, when it is carried upon the fields requiring it.

This method presents many imperfections. In the first place, several successive layers being formed, no two of them can have undergone the same degree of fermentation; in some it will have gone on for six months, and in others but for fifteen days. In the second place, the heap, being exposed to rains, will, by frequent washings, have parted with nearly all its salts and soluble juices. In the third place, the extractive portions of the lower and central parts of the mass, the mucilage, the albumen, and the gelatine, will be entirely decomposed; and, lastly, those gases which nourish plants, if developed at their roots, will have escaped into the air; and Davy has observed, that, by directing these emanations beneath the roots of the turf in a garden, the vegetation was rendered very superior to that in the vicinity.

How long should dunghills be allowed to ferment; and what methods ought to be pursued in forming them? This question leads us to cast a glance upon the nature of dunghills; and it is not till after having ascertained the difference amongst them, that it can be answered.

The principal parts of vegetables which are employed as manure contain mucilage, gelatine, oils, sugar, starch, extractive matter, and often albumen, acids, salts, &c. with an abundance of fibrous matter, insoluble in water.

The different substances afforded by animals, including all their excretions, are gelatine, fibrine, mucus, fat, albumen, urea, uric and phosphoric acids, and some salts.

The greatest part of the substances, constituting animals and vegetables, are soluble in water ; and it is evident that in that state they can be employed as manures without previous fermentation ; but it is necessary, that those which contain much insoluble matter should be decomposed by fermentation, because by that process their nature is changed, and they form new compounds, which, being capable of solution, can pass into the organs of plants.

Messrs. Gay-Lussac and Thenard have obtained, by an analysis of the woody fibre, oxygen, hydrogen, and especially more carbon, than from any other part of the plant, and they have determined their several proportions. We know that fermentation carries off much carbon ; it is then evident that, by causing the fermentation of the vegetable fibre, the principle which forms its distinguishing characteristic will be gradually diminished, and that it will no longer be a body insoluble in water. It is in this manner that woody plants and the driest leaves are converted into manure.

But as all the solid parts of plants contain fibres which cannot be rendered soluble in water, but by a long period of fermentation ; and as it is in the fibre that carbon, a principle so necessary to vegetation, chiefly exists, the fermentation of plants is indispensable to the procuring of the best part of their manure.

The custom of appropriating some crops whilst green to the manuring of the ground, may perhaps be objected to ; but I have observed, that in that case the plants are buried in the earth at the time of flowering ; and whilst they are succulent, and their fibres soft, and but little formed ; and that warmth and the action of water in the earth was sufficient to decompose them : this would not take place if the stalks were dried and hardened by the formation of the grain.

The dung of quadrupeds may be mixed advantageously with the earth at the time of being taken from the stable, if it contain no litter ; but if it does, it appears to me better to cause it to undergo a slight fermentation, in order to dispose the straw or leaves of which it is composed to become manure.

It is necessary, in producing the fermentation of dung and litter, to use certain precautions by which the inconveniences arising from the usual mode may be avoided.

Instead of heaping up in large masses the collections of the barn-yard and stables, and allowing them to rot uncovered, and exposed to the changes of weather, they should be placed under a shed, or be at least protected from the rain by a roof of straw or heath. Separate layers should be formed of each clearing of the stables, cow-house, and sheep-pens. These layers should be from a foot and a half to two feet in thickness; and when the heat, produced in them by fermentation, rises in the centre to more than 95°, or when the mass begins to smoke, it should be turned, to prevent decomposition from going too far.

Fermentation should be arrested as soon as the straw contained in the heap begins to turn brown, and its texture to be decomposed. To do this, the mass may be spread, or carried into the fields, to be immediately mixed with the soil; or there may be mixed with it mould, plaster, turf, sweepings, &c.

When the dung is not of the usual consistency, as is the case with that of neat cattle during the spring and autumn, it ought to be employed immediately, as I have already stated; but if it be impossible to apply it to the fields whilst recent, it should be mixed with earths or other dry and porous substances, which may serve as manures for the fields destined to receive it.

Upon nearly all our farms the dung of quadrupeds is exposed to the open air, without the protection of a shed, as soon as it is removed from the stables; and is thus washed by the rains, which carry off all the salts, urine, and soluble juices, and form at the foot of the mass a rivulet of blackish fluid, which is either wholly evaporated or lost in the ground. In proportion as fermentation advances, new soluble combinations are formed, so that all the nutritive and stimulating principles of the dung gradually disappear, till there remain only some weak portions of the manure, intermingled with stalks of straw which have lost all their goodness.

To remedy as much as possible an abuse so injurious to agriculture, it is necessary at least to dig a deep ditch to receive all the juices which flow from the dunghill, in order that they may be used in the spring upon the corn or grass lands; or they may be preserved to water the grass lands with, after the first mowing. A large cask, fixed upon a small cart, and which can be filled by means of a hand pump, is sufficient for this purpose. Beneath the tap of the cask must be fitted a narrow chest about four feet long, with the bottom pierced with holes, through which the liquor may be scattered. This mode of watering, when used after mowing, produces wonderful effects upon the crop of the following year.

Before deciding upon the question, whether dung and litter should or should not be made to ferment, it is necessary to take into consideration the nature of the soil to be manured. If this be compact, clayey, and cold, it is better that fermentation should not have taken place, as two effects will be produced by the application of the manure in an undecomposed state. In the first place it will improve the soil by softening and dividing it, so as to render it permeable by air and water; and in the next place it will, whilst undergoing the successive processes of fermentation and decomposition, warm the soil. If, on the contrary, the soil be light, porous, calcareous, and warm, the thoroughly fermented manure, or *short muck*, as it is called by farmers, is preferable, because it gives out less heat, and instead of opening the earth, already too porous, to the filtrations of water, it moderates the flow of that fluid. Long experience has made these truths known to observing, practical farmers.

When it is required to apply dung to any particular kind of soil, it is necessary that it should be used according to a knowledge of its qualities. The dung of animals bearing wool is the warmest; next, that of horses; whilst that of cows and oxen contains the least heat of any.

Soft or fluid animal substances change the most easily; and the progress of their decomposition is rapid in proportion to the diminution of the quantity of earthy salts contained in them. Their decomposition produces an abundance of ammonial gas. This circumstance distinguishes them from vegetable substances, the decomposition of which gives rise to the production of that gas, only as far as they contain a small portion of albumen. It is particularly to the developement of ammonial gas, which, combined with gelatine, passes into plants, that we can attribute the wonderful effect produced upon vegetation by certain dry animal substances, of which we shall speak presently.

Next to the dung of animals, of which I have just spoken, the urine of horned cattle and of horses is the most abundant manure which can be used in agriculture; and it is not without regret that I see every day so little pains taken to collect it. I have already observed, that in those countries where agriculture is conducted with the most care and skill, all the stables are floored, and the bottoms of them gently sloping, so as to conduct all the urine into a reservoir, where the remains of rape-seed, flax, wild cabbage, human excrements, &c. &c. are thrown into it to undergo fermentation. In the spring, when vegetation begins to be developed, this fermented liquor is carried into the fields to water the crops.

There are few animal substances of which the nature varies as much as that of urine; the quality of food, or the state of health, produces a sensible change in it. The urine of animals is more or less abundant and active in its qualities, in proportion as their food is juicy or dry. Those which live upon dry fodder give less urine than those which are fed upon green herbage; but that of the first contains a greater quantity of salts than that of the last; and that which is produced directly by drink, contains less animal matter than that which is secreted from the blood by the urinary organs. There are different states of individuals, which may explain satisfactorily the disagreements in the results which have been given, by the numerous analyses which have been made of this fluid.

Mr. Brandt has found the urine of a cow to contain,

Water	65
Phosphate of lime	5
Muriate of potash and of ammonia	15
Sulphate of potash	6
Carbonate of potash and of ammonia	4
Urea	5
	100

Messrs. Fourcroy and Vauquelin have extracted from that of the horse,

Carbonate of lime	11
Carbonate of potash	9
Benzoate of soda	24
Muriate of potash	9
Urea	7
Water and mucilage	940
	1,000

An analysis of human urine by M. Berzelius afforded,

Water	933
Urea	30.1
Uric acid	1
Muriate of ammonia, free lactic acid, lactate of ammonia, and animal matter	17.4
	981.5

The remainder is composed of sulphates, phosphates, and muriates.

It may be seen from these analyses, that there is a wide difference in the urine of various animals, but that all contain salts which enter into plants, with the water by which they are held in solution; and draw in at the same time those animal portions, which, like urea, are easily soluble, and can be decomposed without difficulty.

Amongst the principles contained in urine, there are some salts undecomposable by the digestive organs of vegetables; such are the phosphate of lime, the muriate and the sulphate of potash. These can serve only to excite and stimulate the organs; but the urea, the mucilage, the uric acid, and other animal matters, must be considered as eminently nutritive. Urine in its recent state should never be employed as manure; it acts with too much force, and has a tendency to dry the plants; it should therefore be either mixed with water, or allowed to ferment.

Urine is very useful for moistening all those substances which enter into composts; it increases the fertilizing properties of each one of them, and facilitates the fermentation of those which need to be decomposed before yielding their nutritive qualities.

Urine, when combined with plaster, lime, &c., forms a very active manure for cold lands.

Bones have, at the present time, become, in the hands of the agriculturist, a powerful agent in fertilizing the soil.

These parts of animals are principally composed of phosphate of lime and of gelatine. Those bones which are most usually employed, contain about equal quantities of phosphate and gelatine. The bones of the ox yield from fifty to fifty-five per cent. of gelatine; those of the horse from thirty-six to forty; and those of the hog from forty-eight to fifty.

The bones of young animals contain more gelatine than those of older animals, and have a less compact texture. The bones of the feet of the elk, the roe-buck, stag, and hare afford, upon analysis, from eighty to ninety per cent. of phosphate.

When bones are to be employed as a manure, they should be ground fine, and thrown into a heap to ferment. As soon as this action shall have commenced, so as to give out a penetrating odor, the mass should be spread upon the earth, and be afterwards mixed with it; or it may be thrown upon the seed, and buried in the ground with it. When seeds are sown in furrows, it is a good method to place some of the ground bones in the furrows with them.

In some countries the fat and a great part of the gelatine are extracted from bones, by boiling them in water, before selling them for agricultural purposes. But by this operation they are deprived of a great part of their fertilizing powers. Upon carefully observing the appearance of a mass of bones under fermentation, I found the surface of a part of them to be covered with a thin coating of an unctuous substance, sharp and biting to the taste. This appeared to me to be formed by the combination of gelatine with ammonia; this last being always developed during the decomposition of all animal substances. The observations of M. D'Arcet, to whom we are indebted for a very valuable work upon gelatine, support this opinion.

It is possible, that, when the ground bones are employed without having been first submitted to the commencement of a fermentation, the gelatine is gradually decomposed in the ground, and the same result at length produced; or, we can conceive that water, acting upon the bones, will dissolve the gelatine, and transmit it to plants; and in both these cases the influence of the bones upon vegetation is very great, whether it be considered as a purely nutritive manure, or in the double connexion of a nutritive and stimulating substance.

When bones are calcined in a close vessel, they yield oil and carbonate of ammonia; the proportion of the phosphate is not sensibly diminished; but the gelatine is decomposed. There remains after the operation from sixty-six to seventy-two per cent. of the weight of the bones employed. This residue, broken and pulverized with care, is of great use in the process of refining sugar. After having been used in this process, and become impregnated with ox-blood and animal carbon, I have found it to be one of the best manures which I could employ for trefoil and clover. It should be scattered with the hand upon the plants, when vegetation begins to be developed in the spring.

Some of the dry parts of animals, as the horns, hoofs, and claws, approach closely to bones in the nature of their constituent principles; but the proportions of these vary prodigiously. In such parts, gelatine constitutes the largest portion; and for this reason they are more esteemed as manure than the bones. M. Merat-Guillot has found but twenty-seven per cent. of phosphate of lime in the horn of a stag, and M. Hatchett, by an analysis of five hundred grains of the horn of an ox, gained only one fifth part of earthy residuum, of which a little less than one half was phosphate of lime.

The clippings and parings of horns form an excellent manure, of which the effect is prolonged during a succession of years, owing to the difficulty with which water penetrates them, and the little tendency they have to ferment.

A very good manure is likewise formed from wool. According to the ingenious experiments of M. Hatchett, hair, feathers, and wool are only particular combinations of gelatine with a substance analogous to albumen; water can only dissolve them by means of fermentation, which takes place slowly, and after a long time.

One of the most surprising instances of fertile vegetation that I have ever seen, is that of a field in the neighbourhood of Montpellier, belonging to a manufacturer of woollen blankets. The owner of this land causes it to be dressed every year with the sweepings of his work-shops; and the harvests of corn and fodder which it produces, are astonishing.

It is well known, that the hairs of wool transpire a fluid which hardens upon their surface, but which possesses the property of being easily soluble in water. This substance has received the name of animal sweat; the water in which wool has been washed contains so much of it, as to make it very valuable as a manure.

I saw, thirty years since, a wool merchant in Montpellier, who had placed his wash-house for wool in the midst of a field, a great part of which he had transformed into a garden. In watering his vegetables he had used no other water than that of the washings; and the beauty of his productions was so great, as to render his garden a place of general resort. The Genoese collect with care, in the south of France, all they can find of shreds and rags of woollen fabrics, to place at the foot of their olive trees.

According to the analysis of M. Vauquelin, this animal sweat is a soapy substance, consisting of a base of potash, with an excess of oily matter, and containing, besides, some acetate of potash, a little of the carbonate and of the muriate of the same base, and a scented animal matter.

The dung of birds is another very valuable manure; differing from that of quadrupeds in the food's being better digested; in containing more animal matter, being richer in salts, and affording some of the principles which are found in the urine of four-footed animals.

The dung of those sea-fowls, which are so numerous in the islands of the Pacific ocean, and of which the excrement furnishes an important article of commerce with South America, as, according to the accounts of M. Humboldt, they import into Peru fifty shiploads of it annually, contains, besides a great quantity of uric acid partly saturated by ammonia and potash, some phosphate of lime, of ammonia, and of potash, as well as some oily matter. Davy found the dung of a cormorant to contain some uric acid.

The good effects resulting from the use of pigeons' dung, in our country, has caused it to be carefully collected. One hundred parts of this, when fresh, yielded to Davy twenty-five parts of matter soluble in water, whilst the same, after having undergone putrefaction, gave but eight; whence this able chymist concluded, with reason, that it was necessary to employ it before being fermented. This is a warm manure, and may be scattered by the hand

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before covering the seed ; or it may be used in the spring upon strong lands, when vegetation appears languid.

The excrement of the domestic fowl approaches nearly in its qualities to that of the pigeon, without, however, possessing the same degree of power. It contains also some uric acid, and may be applied to the same purposes as pigeons' dung.

In the south of France, where they raise many silk-worms, they make great use of the larvas, after the silk has been spun from the cocoons. They are spread at the foot of the mulberry and other trees, of which the vegetation is in a languishing condition ; and this small quantity of manure reanimates them surprisingly. Upon distilling some of these larvas, I found more ammonia than I have ever met with in any other animal matter.

Night soil forms an excellent manure; but farmers allow it to be wasted, because it is too active to be employed in its natural state, and they know not how either to moderate its action, or to appropriate it during different stages of fermentation to the wants of various kinds of plants.

In Belgium, which has been the cradle of enlightened agriculture, and where good modes of cultivation are continued and constantly improved, they make astonishing use of this kind of manure. The first year of its decomposition, they cultivate upon the soil to which it is applied, oleaginous plants, such as hemp and flax ; and the second year sow the land with corn. They likewise mix water with urine, and use it to water the fields in the spring, when vegetation begins to unfold. This substance is likewise dried and scattered upon fields of cabbage.

The Flemings value this kind of manure so much, that the cities set a high rate upon the privilege of disposing of the cleansings of their privies ; and there are, in each one of them, sworn officers for the assistance of those who wish to make purchases. These officers know the degree of fermentation suited to each kind of plant, and to the different periods of vegetation.

We shall find great difficulty in bringing this branch of industry to the same degree of perfection amongst us, that it has arrived at in Belgium, because our farmers do not realize its importance, and have a repugnance to employing this kind of manure. But, could they not collect carefully all these matters, mix them with lime, plaster, or gravel, till the odor was dispelled, and then carry the whole upon the fields?

Already, in most of our great cities, the contents of the privies are used for forming *poudrette:* this pulverulent product is sought for by our agriculturists, who acknowledge its good effects; let us hope, that, becoming more enlightened, they will employ the fecal matter itself, as being more rich in nutritive principles, and abounding equally in salts; they can easily govern and moderate the too powerful action of this, by fermentation, or what is still better, by mixing with it plaster, earth, and other absorbents, to correct the odor.

As dunghills are the riches of the fields, a good agriculturist will neglect no means of forming them; it ought to be his first and daily care, for without dung there is no harvest. The scarcity of dunghills, or what is the same thing, the bad state of the crops, sufficiently proves the prejudices, by which the peasant is everywhere governed, and the habitual blindness with which he proceeds in his labors. In our country, many of those who cultivate the land, know only the kinds of straw which are suitable for furnishing manure, and in a dunghill of litter, consider them as acting the principal part, whereas they are only feeble accessories.

According to the experiments of Davy, the straw of barley contains only two per cent. of substance soluble in water, and having a slight resemblance to mucilage; the remainder consists entirely of fibre, which can be decomposed only after a long time, and under circumstances calculated to facilitate the operation.

I do not believe that there is in the whole vegetable kingdom, an aliment affording so little nutriment, either for plants or animals, as the dry straw of grain; serving only to fill the stomachs of the latter, and furnishing to the former but about one hundredth part of its weight of soluble manure.

Weeds, leaves of trees, and all the succulent plants which grow so abundantly in ditches and waste lands, under hedges, and by the road side, if cut or pulled when in flower, and slightly fermented, furnish from twenty to twenty-five times more manure than straw does. These plants, carefully collected, furnish to the agriculturist an immense resource for enriching his lands. Besides the advantage arising from the manure furnished by these plants, the agriculturist will find his account in preventing the dissemination of their seeds, which, by propagating in the fields, deprive the crops of the nourishment of the soil. The turf, that borders fields and highways, may be made to answer the same purpose, by cutting it up with all the roots and the earth adhering to them, rotting the whole in a heap, and afterwards carrying the mass upon the fields, or what is still better, by burning it, and dressing the land with the products of the combustion.

If straw did not serve as beds for animals, and did not contribute, at the same time, to their health and cleanliness, it would be better to cut the ears of corn and leave the stalks in the fields; since they serve only as absorbents of the true manures.

It is always said that barn-yard manure, besides its nutritive virtues, possesses the advantage of softening hard lands, and rendering them permeable by air and water. I do not deny the truth of this; I even acknowledge that it owes this property almost entirely to the straw which it contains; but the same effect would be produced by burying the straw upon the spot.

Besides the characteristic of providing plants with food, the various kinds of dung possess other qualities, which add to their fertilizing powers. Dung, as it is applied to the ground, is never so much decomposed as to have ceased fermenting; and from the moment it is mixed with the soil it produces in it a degree of warmth favorable to vegetation, and serving to guard the young plants against the effects of those sudden returns of cold in the atmospheric temperature, which are so often experienced. On account of the viscous fluids which it contains, dung is not easily dried, unless it be in contact with the air. It therefore preserves the roots of the plants in a state of moisture; and supports vegetation at those periods, when, without it, plants would perish from drought. It likewise contains many salts which are transmitted by water to plants, serving to animate and excite their functions. The various kinds of dung, mixed with earth, may be considered in the light of amendments to the soil; and in this view they ought to vary according to the nature of the earth to be improved. Compact soils require to be separated and warmed; they require, then, those manures which have been but slightly fermented, and that are the richest in salts. Calcareous and light earths require oily manures, which decompose slowly, and can retain water for a long time, to furnish it to the wants of plants in seasons of drought.

It is by separating these principles, that we may be able to appropriate the various kinds of manure to each species of soil and plant: the attention of agriculturists is already directed, upon this point, to the composition of mixtures of manures, called composts. These are formed by arranging, one above another, beds of different kinds of manure, taking care to correct the faults of one by the properties of another, in such a manner as to produce a mixture suited to the soil to be enriched by it.

For example, if it be required to form a compost for a clayey and compact soil; the first bed must be made of plaster, gravel, or mortar rubbish; the second, of the litter and excrements of horses, or sheep; the third, of the sweepings of yards, paths, and barns, of lean marl, dry and calcareous; of mud deposited by rivers, of the fecal matter collected upon the farm, the remains of hay, straw, etc., and this in its turn must be covered with a laying of the same materials as the first. Fermentation will take place first in the beds of dung, and the liquor flowing from these will mingle with the materials of the other layers; when the mass exhibits the signs which I have pointed out, as indicating decomposition to be sufficiently advanced, it must be carried into the fields, care being first taken to mix well the substances composing the different layers.

If the compost be designed to manure a light, porous, and calcareous soil, it must be formed of materials of a very different character. In this case it is necessary that argillaceous principles should prevail; the substances must be compact, the dung of the least heating kind, and the fermentation continued, till the materials form a yielding and glutinous paste; the earths must be clayey, half baked, and pounded, or consisting of fat and argillaceous marl, and mud from the sea coast. Of these all the layers must be formed.

By following these principles in my operations, I have completely changed the nature of an ungrateful soil in the neighbourhood of one of my manufactories. Over this soil, composed of calcareous earth and light sand, I spread, during several years, some calcined clayey earth; and this land, upon which I could formerly raise only stone fruit, has become adapted to fruit containing kernels; and produces excellent wheat, whereas before it bore only scanty crops of oats and rye.

ARTICLE II.

Of Stimulating Manures.

I HAVE hitherto spoken only of those manures which contain, at the same time with aliments necessary for vegetation, the salts which are inseparable from them; and which pass, in a state of solution, into the organs of plants to stimulate their action. I shall now speak particularly of these salts, explaining in what manner they act, and how their utility in vegetable economy differs materially from that of the alimentary principles; and showing that they can often be so employed as to increase the activity of vegetation.

It appears from the results of the critical experiments which M. Saussure has made upon these substances, that the salts and extracts, when dissolved in water, are absorbed by the roots of plants.

The absorption of hurtful salts is easy and abundant, in proportion as the plant is languishing, sickly, or mutilated. From this principle, established by experiments, it follows that the absorption of fluids and salts by the plants is not a passive and purely physical faculty; but one, which is determined by those laws of vitality, which govern the plant during life. It is only when the power of these laws is weakened by a sick or languishing state of the plant, that external agents can act upon it in an absolute manner. Plants do not draw in indifferently, or in the same quantities, all substances which can be held in solution by water; they absorb, from preference, those which are least viscid.

From the preceding statements it is rational to conclude, that plants do not maintain a strictly passive state in regard to their aliments; but that to a certain degree they have a preference, and taste, respecting them; and that the physical laws predominate, to the injury of the vital organization, in proportion to the sickly or languishing condition of the plant.

All the soft and fibrous portions of plants, are evidently the product of the elaboration carried in their organs, of the juices and gases by which they are nourished. The saline particles, which plants contain, are unchanged, and such as are furnished by the soil.

Whatever may be the variety of products presented to us by the vegetable kingdom, the elements which compose them are few in number. They contain only oxygen, carbon, hydrogen, and azote, combined in an immense variety of proportions ; some hundredths more or less, in the proportions of these constituent principles, often cause an astonishing difference in the character of their products. It is this which occasions the slightest alteration produced in the organs to give rise to new compounds, bearing no resemblance to the first.

No one has ever disputed that the juices, the oils, the resins, the fibre, and other essential parts of vegetation, are the result of the action of the different organs of plants ; and that the elements composing them were those of the bodies by which they are nourished, and which each combines in a manner peculiar to itself, and fitted to its own organization. There is, in all this, nothing like creation, but simply decomposition upon one side, and, upon the other, a new combination of the elements, in different proportions.

Many philosophers, in other instances very correct, have asserted that plants themselves form, even by the act of vegetation, salts and earths ; but, as science has advanced, it has been ascertained that none of the experiments cited by them have been made with exactness. Some have watered plants with distilled water ; others have raised them in washed sand ; nearly all have allowed free access of the air to them ; many have analyzed, with a certain degree of care, the soil upon which they raised their plants ; and nearly all have concluded, that the salts and earths which they found in them, and of which they could demonstrate neither the existence, nor even the quantity if found, in the different substances concurring to produce vegetation, must be the work of the plant. But does not the often disturbed atmosphere frequently change the salts, and the earths, which it deposits upon plants ? Does not the dust which it carries, alight upon the upper surfaces of leaves and branches ? Water, the best distilled, according to the experiments of Davy, contains some alkaline and earthy atoms.

Messrs. Schrader and Braconnot have published the results of their experiments, by which they have been led to believe, that salts and earths are created in the organs of plants; but M. Lassaigne has proved, that the salts and earths, contained in the developed plant, are the same as those that are found in the seed from which they sprang.

M. Th. de Saussure, whose opinion upon these matters is of great weight, has proved that plants do not create any of these substances.

Besides, if the formation of certain salts be a power of the plant itself, why does not the salsola afford more marine salt when it grows at a distance from the sea? Why, under the same circumstances, does not the "*tamarisk*" furnish more sulphate of soda? and, finally, why does the turnsol remain destitute of salt-petre, if raised upon a soil which does not contain it?

Be this doctrine as it may, there are two practical truths which we do know; the first is, that certain salts enter, if I may so speak, as natural elements into the composition of some plants; since it is found that they languish in earths not containing those substances; and that the plants absorb them abundantly, when they are present. The second is, that the salts ought always to be united with manures; the excellence of which is increased, in proportion to the quantity they contain, provided it do not exceed the wants of the plants, and that the action be not too energetic.

I may add, that a plant absorbs, from preference, the salt most analogous to its nature. The salsola, which grows by the side of the tamarisk, sucks up from the earth marine salt; whilst the tamarisk imbibes from it the sulphate of soda. It is proved by the analysis of plants of different kinds, that have been raised upon the same ground, that they do not furnish the same salts, or that, at least, they present a great difference in the quantities they contain.

The salts are necessary to plants; they facilitate the action of their organs so much, that they are often employed without mixture.

Limestone submitted to the action of fire loses the carbonic acid, which is one of its constituent principles, and the result is a whitish stone, opaque and sonorous, of a sharp and burning taste, absorbing water with noise and heat, and forming with it a paste, which is a perfect hydrate. Good limestone may be deprived of 50 per cent. of its weight by calcination, but it is seldom that the heat of the kilns is sufficient to deprive it of more than from 35 to 40 per cent. when the carbonate is dry.

As soon as lime is exposed to the air, it absorbs moisture from it with great readiness; gradually cracking and breaking in pieces. It likewise absorbs the carbonic acid contained in the atmosphere, and is thus insensibly reduced to an impalpable powder.

In this manner, lime resumes the principles of which it had been deprived by calcination, and is reconstituted limestone, or calcareous carbonate, without regaining its solidity. In proportion as the recomposition goes on, the lime loses the properties which it had acquired from the action of fire; it ceases to be caustic, its solubility in water is diminished, and its affinity for that fluid becomes almost nothing.

The lime used in agriculture is that which has been slacked by air. Unslacked lime destroys vegetation, at least if it be not combined with manures which moderate its action, or with such bodies as can furnish enough carbonic acid to saturate it.

We are indebted to Davy for some experiments which throw a great light upon the action of lime upon vegetation. He has proved that the fibrous portion of plants, deprived of all the particles which can be dissolved by water, presents another series, soluble after having been for some time macerated with lime. Thus lime may be very efficaciously employed, when it is wished to convert dry wood or fibrous roots, and stalks, to the nourishment of plants. Limestone broken, and lime completely restored to the state of a carbonate, do not produce this effect; it is necessary to employ lime slacked with water, and mixed with a fresh portion of that fluid, and the fibrous substances must remain for some time exposed to the action of this solution. In the case of which I have just spoken, the lime renders soluble and suited to the nourishment of plants, some substances, which, in their natural state, do not possess this characteristic; and for this purpose the use of it may be very advantageous. Thus, when it is desirable to convert ligneous and fibrous plants into manure, it may be done by treating them with lime.

If it be required to employ, as manure, some substances, whether animal or vegetable, which are by nature soluble in water, their mixture with lime forms new compounds of natures completely different from their constituent principles, but which may, in time, become very proper for the nutriment of plants: this requires some explanation.

The compounds formed by lime with nearly all the soft animal or vegetable substances which will combine with it, are insoluble in water; accordingly, lime destroys or greatly diminishes the property of fermentation in the larger part of them; but these same compounds at length undergo a change from being exposed for a length of time to the constant action of air and water; the lime passing to the state of a carbonate, and the animal and vegetable substances being gradually decomposed, and furnishing new products capable of supplying nourishment to plants; so that lime answers two great purposes for nutriment; first, it disposes certain insoluble bodies to form by their decomposition soluble compounds; and, secondly, it prolongs the action and nutritive virtue of some soft and insoluble animal and vegetable substances, beyond the term they would continue to act if they were not made to enter into combination with lime.

Very striking instances of the facts which I have just stated, may be found in some of the operations performed in various branches of manufactures. For instance, in the process of refining sugars to free them from the vegetable extract and the albumen which they contain, the milk of lime is employed, which, combining with these substances, rises to the surface of the liquid in the form of a thick and insoluble foam or scum; this, if carried immediately into the fields, destroys vegetation, but if deposited in a ditch during a year, it forms one of the most fertilizing manures with which I am acquainted. I have established this fact by having employed, in this manner, during the period of a dozen years, the abundant foam arising from the first operations performed upon the sugar of beets in my manufactory.

From the explanation which I have given of the manner in which lime acts, we may draw some conclusions in regard to its uses, and to the manner in which it should be employed in order to have the results, arising from its application, conform to those which have been produced by enlightened experiments.

It is acknowledged that lime is principally useful upon fallow lands which are broken up; upon grass lands, whether natural or artificial, which are prepared for cultivation; and upon muddy lands, which are to be put into a state fit for culture. It is well known, that in all these cases there exists in the land a greater or less quantity of roots, which, by the application of lime, may be made to serve more immediately for manure, by the solubility it will give to the new products formed by them; but this effect can be produced neither by spreading the lime on the land at the time of sowing the seed, nor by throwing it upon the soil without covering it, nor by sprinkling it upon the plants which have begun to unfold; it is necessary to scatter it upon the land before the first tilling, and only as fast as it can be mixed with the soil, as lime loses its strength by exposure to the air. Subsequent tillages mix it more intimately with the soil, and place it in contact with the roots and stalks upon which it is to act, and at the end of some months this action is completed.

Independently of this effect, which, in my opinion, is the most important, lime exercises other powers, which make it a very valuable agent in agriculture. It cannot be denied, that the long existence and the barrenness of a marshy or turfy soil, give rise in such lands to myriads of insects, which repeated tillages, and frequent changes of crops, can destroy only in a great length of time; whilst the mixture of lime with the earth performs the work immediately. It is certain, that some plants which injure the soil and the crops, escape every tilling; but are immediately destroyed by the action of lime. It is clear, that to produce these effects, the lime must be applied in the caustic state; the mode of preparing it is as follows.

As lime absorbs water with avidity, exhaling vapor and producing noise and heat, and crumbling into pieces, that liquid may be thrown upon it, till the whole mass is reduced to a dry and impalpable powder; and it is in this state that it must be used.

In order to preserve the husbandman from the deleterious effects upon the lungs, of this light powder, it is best to mix it with some moistened earth; and in order that it may preserve all its virtue, it is necessary that it should be immediately buried in the soil by ploughing.

The custom of employing air-slacked lime, which is lime in the state of a sub-carbonate, is spreading in France every year, and is productive of good results. This lime is, undoubtedly, less active than that which has been slacked by water; but it requires fewer precautions in the use of it, and is not liable to so many inconveniences.

When lime has been acted upon by the air, till it is reduced to the state of an impalpable powder, it is used with great advantage by mixing it with dunghill manure; it serves to correct the acidity arising from the decomposition of certain portions of this, such as the mash of grapes, &c. &c., and it absorbs the juices that would flow off and be lost, or would be too rapidly decomposed; it likewise fixes the gases, which would otherwise ascend into the atmosphere. This mixture spread upon the fields excites vegetation, warms cold soils, divides those which are compact, regulates the fermentation of manures, and furnishes to plants, gradually, and in proportion to their wants, the nutritive principles with which it is impregnated.

Lime slacked by air does not entirely lose the property of being soluble in water, and when used it is carried into the organs of plants by that liquid, producing those good effects which arise from the employment of saline substances, in small quantities.

Limestone saturated with carbonic acid, though it may be reduced to powder, does not produce any of the good effects arising from the use of quick-lime, or of that which has been slacked by air. Its almost sole use is to divide compact earths, to facilitate the passage of water through them; and to dispose them to yield more readily to tillage.

Limestone often contains some magnesia, which exercises a singular power in modifying the action of the lime. M. Tennant obtained from 20 to 22 per cent. of magnesia from limestone, in which the lime was in the proportion of only from 29 to 31 per cent., by throwing upon this mixture a little more nitric acid, diluted with water, than was necessary to saturate it; the liquor remained turbid, and of a whitish color.

I have always observed that all earths, of whatever nature, containing magnesia, render the waters covering them whitish; and that the agitation of these waters by the wind takes from them all their transparency. When such waters form ponds or pools, they are called white waters.

Magnesian earths possess but little fertility; and when the lime employed for agricultural purposes contains magnesia, its beneficial effects do not follow. In order to account for this difference of action, it is necessary to take into consideration, that magnesia has less affinity for carbonic acid than lime has, and that, consequently, when the two earths are mingled together, the magnesia preserves its causticity, even when the lime is saturated with carbonic acid, and brought back to the state of lime-stone. Thus it appears that magnesia can preserve its caustic properties, and exercise its deleterious effects upon vegetation, during a long time.

The use of plaster, or gypsum, which has become common in Europe as a manure, is one of the most important improvements that has ever been made in agriculture. It has even been introduced into America, where it was made known by Franklin upon his return from Paris. As this celebrated philosopher wished that the effects of this manure should strike the gaze of all cultivators, he wrote in great letters, formed by the use of the ground plaster, in a field of clover lying upon the great road to Washington, "This has been plastered." The prodigious vegetation which was developed in the plastered portion led him to adopt this method. Volumes upon the excellences of plaster would not have produced so speedy a revolution. From that period the Americans have imported great quantities of plaster of Paris.

There are, however, some tracts of country where the use of plaster has been attempted without success. But this arose from its being one of the original constituents of the soil, which derived no advantage from the addition of a new quantity. The existence of this salt, naturally, in those lands upon which plaster produced little or no effect, has been proved by analysis.

Gypsum is a compound of sulphuric acid and lime, containing more or less of the water of crystallization. A moderate heat deprives it of its water of crystallization, and renders it opaque. It can then be reduced to powder, and employed in that state. Though the prepared gypsum absorbs water with avidity, and its consistency is affected by the mixture, it may be preserved many months without its properties being sensibly affected. Nothing more is necessary for this purpose than to head it up in tight casks.

Gypsum carefully broken is likewise much used; and there are some farmers who attribute to it the same efficacy as is possessed by that prepared by heat. I have myself made some comparative experiments, and observed, that the baked plaster evidently produced a little more effect the first year, but during the three years which followed, the difference was almost nothing.

The gypsum is scattered by the hand at the time when the leaves of the plants begin to cover the ground, and it is best to take advantage of a light rain for the operation, as it is thought to be beneficial to have the leaves moistened, in order that they may retain a small portion of the powder.

The effect of the gypsum is perceptible during three or four years. The use of it can be resumed at the end of that time. The quantity in which it is usually employed is from $2\frac{3}{4}$ cwt. to $3\frac{1}{8}$ cwt. per acre.

Much has been said upon the effects of plaster. Some have pretended that its action ought to be attributed to the force with which it absorbs water. But it solidifies that liquid, and does not part with it either to the atmosphere, or to any other surrounding body; so that this doctrine does not appear well founded. Besides, if its action were from this cause, it would be momentary, and would cease after the first rains; and this is contradicted by experience. Moreover, it is believed that the broken gypsum has not the property of absorbing water; and yet it produces nearly the same effects as the baked and powdered plaster.

Others have thought that plaster acted only by favoring the putrefaction of animal substances and the decomposition of manures. But Davy has refuted this opinion by direct experiment, placing it beyond a doubt, that the mixture of plaster with manures, whether animal or vegetable, does not facilitate decomposition.

There are others, again, who attribute the effects of plaster to its stimulating properties; and these adopt, in its utmost extent, the opinion which I have formed upon the subject. It still remains, however, to be explained, why this salt, which is not more stimulating than many others, acts with so much better effect, and why its action is continued during several years, whilst that of others is exhausted in so much less time; why this salt never dries plants, whilst the others, if employed in excess, burn them up and destroy them. These are problems which remain to be solved, and of which the solution cannot be found in the stimulating properties of the plaster.

Hitherto it has been sufficient to state the good effects of plaster, in order that agriculture might be enriched by so important a discovery. The fact alone is sufficient for the farmer, and it is not the only one in which the theory can add nothing to the practice. I shall, however, give here a few of my ideas upon the action of plaster; and I publish them with the more confidence, because they appear to me to be deduced from well-established analogies.

It is proved, that those salts which have a base of lime or alkali are the most abundant in plants. Analysis also shows that the different salts do not exist in the same proportions, either in plants of different kinds, or in the different parts of the same plant.

On the other hand, observation shows us every day, that these substances, to be beneficial to plants, must be presented to them in proper proportions; for if too great a quantity of salts easily soluble in water be mixed with the soil, the plants will wither and die; though they will languish, if totally deprived of the salts. A little marine salt, mixed with dung and spread upon the soil, excites the organs of plants and promotes vegetation; but too much will produce a pernicious effect upon them.

If we now consider that salts can act upon plants, only in proportion to their solubility in water, through which medium they are conveyed, we can conceive, that those which are least soluble will be productive of the greatest advantage.

Water can hold in solution at any one time but a small portion of these saline substances; and as they will always be conveyed into plants in the same proportions, their effect will be equal and constant, and will be continued till the soil be exhausted of the salts. The length of this period will be according to the quantity of them which is contained in the soil, and to the plants not being rendered liable to receiving more of them than it needs.

The solubility of plaster in water appears to be precisely of the degree most beneficial; 300 parts of water will dissolve only 1 of plaster. Its action is therefore constant and uniform, without being hurtful. The organs of plants are excited by it without being irritated and corroded, as they are by those salts which, being more soluble in water, are carried more abundantly into plants, producing upon them the most injurious effects.

The greater part of those salts which are found in plants serve no purpose of nourishment; they are generally useful only as stimulating the organs and aiding digestion. Animals, as they enjoy the power of locomotion, can easily procure for themselves these stimulants and whatever is needful for the exercise of their offices, and they take only such quantities and in such proportions as are suitable for them. But plants have no other medium than air and water, through which to receive their supplies; and this last transmits to them indiscriminately all which it can dissolve from the soil; whence it follows, that the best saline manures are those that can be only gradually dissolved.

This principle is applicable to all manures of whatever nature. There is, however, this difference in the effects of manures purely nutritive, and of the stimulating or saline manures; if the first be too abundant, the plant absorbs more nourishment than it can readily digest, and becomes affected by a kind of obesity; the texture of its organs is rendered soft, loose, and spongy, and unable to give to their products the due degree of consistency; whilst, on the contrary, if the stimulating manures be supplied too profusely, and especially if they be of kinds very soluble in water, the organs of the plants are dried and parched by the excess which they receive.

Those animal substances that are the most slowly decomposed, and which by their decomposition always give rise to soluble products, are the best of all manures: of this bones, horns, and wool, afford a sufficient proof. These substances possess the advantage of affording to plants their suitable aliments, almost always combined with a stimulant, such as ammonia, of which the too irritating action is moderated by its union with carbonic acid or with animal matter.

The ashes of turf and of pit coal produce wonderful effects upon grass lands. The first of these often contains gypsum, but frequently only silica, alumina, and oxide of iron. From ashes of pit coal I have obtained by analysis sulphuret of lime.

The ashes, produced by the combustion of wood in our common domestic fires, give rise to some very remarkable results. Without being leached these ashes are much too active; but after having been deprived, by the action of water, of nearly all their salts, and employed in this state, under the name of *buck-ashes*, they still produce great effect.

The action of the buck-ashes is most powerful upon moist lands and meadows, in which they not only facilitate the growth of useful plants, but if employed constantly for several years, they will free the soil from weeds. By the use of them, land constantly drenched with water may be freed from rushes, and prepared for yielding clover and other plants of good kinds. Wood ashes possess the double property of amending a wet and clayey soil by dividing and drying it, and of promoting vegetation by the salts they contain.

CHAPTER IV.

OF GERMINATION.

Oxygen, heat, and water are almost the sole agents in the act of germination.

Pure water, when imbibed by a seed, as a grain of wheat, for instance, increases its volume, and facilitates the developement of the germ. But the first of these effects is entirely physical, and takes place in the dead as well as in the living seed, as has been proved by M. de Saussure. Water changes neither the odor nor the taste of seeds. A grain of wheat, deprived of its vital principle, is, by the action of water, disposed to putrefaction; whilst in one which is living, the fluid contributes to the developement of a succession of new powers.

There are some seeds that can germinate under water; but it is only through the quantity of air contained in that liquid that it then operates in assisting germination. The developement of the germ will not take place in water completely deprived of air; and when the water contains but little air, it is necessary, to its producing the same effect, that the volume of it should be increased.

Seeds, whilst germinating, absorb oxygen, and surround themselves with an atmosphere of carbonic acid. This, however, does not take place if the seed be in contact with the atmospheric air, or with water containing much air.

If seeds are secluded from air and moisture whilst fresh and succulent, they putrefy; but if previously dried, they do not undergo this change, but preserve their power of germination, till exposure to air and moisture calls it into action.

The activity of germination is proportioned to the degree of oxygen contained in the air. The larger seeds imbibe more of this gas than the smaller.

Seeds, whilst germinating, exhale only carbonic acid; and the volume of oxygen they consume is always equal to the volume of carbonic acid produced. All these results have been ascertained by the beautiful experiments of M. de Saussure. It appears, then, that the only agent in germination is oxygen; the only product carbonic acid. The seed parts with a certain portion of carbon, and the oxygen combines with no other principle of the seed. For if a seed be made to germinate in 100 inches of atmospheric air, containing 21 inches of oxygen, it will be found that germination has produced 14 cubic inches of carbonic acid, and that there remains 7 cubic inches of free oxygen in the portion of atmosphere in which the process of germination has been going on. It is evident, then, that, in this first stage of vegetation, water does not furnish the seed with any additional principle, and that it is not itself decomposed. It is not, however, useless to vegetation, since it is a well-known fact, that well-dried seeds may be preserved from germination though brought in free contact with the air.

Water appears to me to produce two undeniable effects in germination. In the first place it penetrates the covering of the seed to deposit within it the oxygen of the air which it holds in solution, in order to produce the formation of the first portion of carbonic acid; and in the second, it opens a free access by which the air can enter into the grain, and act upon it in the manner already pointed out.

From what I have already stated, it follows, that germination cannot well be carried on, unless the atmospheric air has access to the seed, which cannot be the case if the seed be buried too deeply in the ground, or if it be sown in a compact soil and closely covered over.

It likewise follows, from these principles, that when the earth remains a long time covered with standing water, the seeds must decay, and also, that a seed placed in dry earth cannot germinate unless it be moistened.

The impossibility of a seed's germinating, when too deeply buried in the ground, explains why we sometimes see, after deep tilling, plants making their appearance, of the same kind as those which had been cultivated upon the soil several years before. The state of the earth as it regards moisture, at the time of sowing, furnishes a reason, independent of the action of heat, why seeds are a longer or shorter time in sprouting.

Seeds do not germinate in pure carbonic acid. Mixed with atmospheric air this gas retards the process of germination; but it may be hastened by absorbing the carbonic acid evolved by the seeds, by means of lime or alkalies.

During the first stages of vegetation the feeble plant rejects those other aliments which, as it advances in strength, become the principal agents in its nutrition.

Germination takes place in the same space of time in darkness as in light. But M. de Saussure has observed, that, after the process of germination was completed, the developement of plants was more rapid and perfect in the light than in obscurity.

Thus we see, that, in the germination of seeds, every thing may be reduced to the following facts.

Water, or moisture, swells the seed, and the oxygen contained in that liquid subtracts from the seed the carbon which is its principal constituent.

The swelling of the seed by water facilitates the introduction of atmospheric air into the interior of the grain, where its oxygen can combine more readily with the carbon for the formation of carbonic acid, which is disengaged under the form of a gas.

The heat necessary for germination facilitates the action of the oxygen and the volatilization of the carbonic acid gas, at the same time that it excites the germ and stimulates its developement.

The subtraction of a portion of their carbon changes the state and the nature of seeds. The mucilage and the starch, of which they are almost entirely composed, by parting with a portion of their carbon, pass to the state of sweetish, milky substances, containing sugar, which is the first nourishment of the embryo plants.

CHAPTER V.

OF THE NOURISHMENT OF PLANTS.

As soon as a plant begins to unfold its leaves, and to fasten its roots in the earth, it is nourished by new aliments, which it receives from the air and the soil by which it is surrounded.

The organs, which convey to the plant its new nourishment, are principally the leaves and the roots. The leaves absorb some of the gases contained in the air; and the roots draw in, with the water containing them, the juices and salts which are mixed with the soil; and the gases which are developed in it are imbibed by them through the medium either of air or water.

ARTICLE I.

The Influence of Carbonic Acid upon Nutrition.

Plants absorb carbonic acid from water and the air. In the light they decompose it, and assimilate the carbon and a part of the oxygen.

A small portion of carbonic acid added to that existing in the atmosphere is favorable to vegetation; too large a quantity is hurtful.

The presence of this gas is indispensable to vegetation, but the want of it is not equally great during all periods of the growth of plants. A very young plant, of which the leaves and roots have just begun to be developed, languishes if watered with water containing the acid. When it has acquired some strength and size, its growth and vigor are increased by the operation. Sennebier has observed, that young leaves decomposed, from an equal volume of air during the same time, less carbonic acid than leaves of full size.

Vegetation can generally be accelerated by mixing with the atmospheric air $\frac{1}{10}$ or $\frac{1}{12}$ of carbonic acid gas; but this addition is not favorable unless the plants are exposed to the sun. In the shade any addition whatever is injurious.

The effects produced by mould, and many other substances which are employed to promote vegetation, are in a great part owing to the carbonic acid gas, which they are continually transmitting directly to the plant by its roots, or throwing out into the atmosphere, whence it is imbibed by the leaves.

The power of absorbing carbonic acid, and of decomposing it, resides principally in the leaves; and the decomposition is very active when they are exposed to the sun, in which case they give out to the atmosphere a large quantity of oxygen combined with a little azote.

According to the experiments of M. de Saussure, plants retain a small portion of the oxygen arising from the decomposition of carbonic acid, and throw out the rest into the atmosphere. The rapidity with which the decomposition of carbonic acid is carried on, is in proportion to the brilliancy of the sun's rays, and to the greenness and freshness of the leaves. It however appears, that decomposition can be performed in the shade, though not very actively; since Sennebier observed, that leaves which unfolded in the dark were sensibly tinged with green, which he attributes to their decomposition of carbonic acid.

I will here mention an observation which I made, a long time since, in the coal mines of Bousquet, in the department of Beziers.

The pieces of wood which support the roof of the long gallery which conducts to the beds of coal, were loaded with that species of mushroom which usually fixes itself upon the trunks of old trees; the entrance of the gallery is very light, but the light gradually diminishes till it is lost in total darkness. I was much struck, in passing through this gallery, with the different appearances presented by the mushrooms in the various degrees of light; those at the entrance were yellow, and their texture so compact that they could hardly be broken by the hand. As I advanced, the reddish yellow color grew gradually fainter, and the texture of the plants more soft and spongy, till at the bottom of the gallery, where a ray of daylight never penetrates, I found the mushrooms, though as large as those at the entrance, perfectly white, and nearly without consistency, so much so, that upon pressing them with the hand, they were found to yield much liquid, and but little fibrous matter. I filled several bottles with these, and took in my hands some of those from the middle and entrance of the gallery. A comparative analysis of these various portions afforded me, from those which grew at the bottom of the gallery, only water saturated with carbonic acid, a small quantity of mucilage, and a little parenchymous fibre swimming in the liquid. The proportion of acid was much less, and that of ligneous fibre more considerable, in the mushrooms plucked from the middle and entrance of the gallery, particularly in the last. Those from the dark part of the gallery contained only the elements of nutrition not elaborated; whilst in the other, the process of assimilation was carried on more or less perfectly, in proportion as light and atmospheric air had access to them to facilitate vegetation; otherwise, as carbonic acid was most abundant in those plants which grew in darkness, their texture ought to have been the most thoroughly impregnated with it.

ARTICLE II.

The Influence of Oxygen Gas upon Nutrition.

Healthy leaves absorb oxygen gas during the night, but the phenomena which they present vary according to the nature of the plant. Those of the oak, the horse-chestnut, the false acacia, &c., absorb oxygen and evolve a less volume of carbonic acid than they consume of oxygen. The leaves of fleshy plants diminish the volume of air by absorbing from it oxygen, without which they sensibly give out carbonic acid.

The quantity of oxygen absorbed by plants is in proportion to their state of vigor. It is likewise regulated by temperature; being greater at 88° than at 55° or at 66° Fahrenheit.

When plants remain several nights under receivers filled with atmospheric air, the leaves continue, though slowly, to absorb oxygen, with which they are saturated as soon as they contain 1¼ their volume. When the leaves are saturated with oxygen they begin to form carbonic acid, by combining their carbon with the oxygen of the atmosphere, without at the same time changing its volume, as they never employ, for the formation of this acid, all the oxygen which they can absorb. The oxygen absorbed by leaves enters into a state of combination in them; the oxygen which can be disengaged from them in a vacuum, by means of heat, amounts to only $\frac{1}{16}$ of the volume absorbed; the gas thus extracted is not pure, but consists of azote, carbonic acid, and oxygen.

It is very probable that the oxygen absorbed by plants growing in darkness, combines with their carbon to form carbonic acid; this remains in solution in their juices, till the sun effects its decomposition, when the oxygen is thrown out into the air by the transpiration of the leaves, whilst the carbon enters into the composition of the plants.

Plants can unfold only in an atmosphere containing oxygen; nevertheless, they thrive less in the shade in pure oxygen, than if it be combined with other gases, as azote and carbonic acid.

The leaves of different plants do not consume in the shade the same quantity of oxygen. Those of fleshy plants absorb but little, which they retain obstinately; and disengage a still less quantity of carbonic acid. As these plants preserve better than others their carbon, and require but a small quantity of oxygen, they can live in soils of but little fertility: they will flourish upon heights where the air is much rarefied, and upon arid sands.

The leaves of those trees which are naked during the winter, are, in general, those which absorb the most oxygen, and contain the most carbon. Not only do these plants prepare all the juices which are essential to vegetation, and to the formation of fruits; but after having fulfilled these functions, they continue to extract, from the earth and air, the principles of their nourishment; these they elaborate and deposit between the bark and the wood, to serve for their first aliment at the return of spring, till the developement of the leaves and the excitement of the roots by heat, can provide for their nourishment by the absorption of foreign substances. The experiments of Mr. Knight have established this theory.

This phenomenon in vegetation bears a close resemblance to that which we observe to take place in the greatest number of insects, in some birds, and in many quadrupeds; which become torpid during the winter, and are nourished, whilst in that state, by the fat deposited in their cellular membranes during the autumn.

Plants growing upon marshes and bogs, and consequently surrounded the greater part of the time by an atmosphere of vapor, consume less oxygen gas than most other herbaceous plants. In general, the quantity of oxygen absorbed by plants, is in proportion to the fertility of the soil in which they grow, and to the quantity of gas contained in the air by which they are surrounded. These inferences have been drawn from the results of numerous experiments made by M. de Saussure.

Healthy roots, separated from their stems, and placed under a bell-glass, diminish the volume of atmospheric air, and form carbonic acid with the surrounding oxygen ; in this case they never absorb a volume of oxygen greater than their own. If a root, thus saturated, be placed under another receiver filled with common air, it will form carbonic acid without changing the volume of the air ; but if it be then exposed to the open air, it will absorb a quantity of oxygen gas nearly equal to its volume, as when it was enclosed under the first receiver ; which proves that free atmospheric air can take from roots the carbonic acid which they form.

It is plain, then, that roots exercise the same action, in regard to oxygen, that leaves do, though they absorb less of it. The only important difference is, that the roots do not decompose the carbonic acid ; this office appears to be confined to the leaves, to which the acid is transported, to be decomposed by the solar rays.

When the root is not separated from the stem, the results differ from the above ; in the last instance, the root absorbs more than once its volume of oxygen ; the reason of this is very simple : the carbonic acid, as soon as it is formed, is dissolved in the juices of the root, passes from that into the stem, thence into the leaves, in which its decomposition is principally performed ; so that the root parts with the carbonic acid as soon as it is formed, and, though it is constantly producing, is never surcharged with it.

Not only do the roots absorb oxygen from the atmospheric air which penetrates to them, but they disengage that which always exists in the water by which they are moistened. This leads to the explanation of a fact which I have often observed. When the roots of almost any tree have become surrounded by stagnant water, enclosed beneath the soil, and secluded from the access of atmospheric air, the tree soon begins to languish, and the leaves to turn yellow and die. In this case it appears that the water has become exhausted of oxygen, without having the power of renewing it, and when that is no longer present for the roots to absorb, they decay; whilst, if the root were supplied with flowing water, it would be constantly receiving fresh supplies of oxygen for the formation of carbonic acid, which furnishes the principal nutrition of the plant.

The wood, the parenchyma, the petals, and, in general, all those parts of plants which are not green, do not inhale and exhale, alternately during the day and night, the oxygen gas which surrounds them; but they absorb a small quantity, which combines with their carbon, and remains in solution in their juices, till it is conveyed to the leaves, when it is decomposed by the rays of the sun. According to this it appears, that carbon, which forms one of the most abundant principles of the juices and other manures which are furnished to plants to supply them with nourishment, cannot be assimilated by them, unless it be combined with oxygen, and form carbonic acid. In this state it is thrown into the atmosphere, whence it is gradually absorbed by the leaves, and decomposed by them. One experiment, which seems to establish this opinion, is that of absorbing, by means of lime or the caustic alkalies, the carbonic acid, as fast as it is transpired by the leaves, the consequence of which is the death of the plant.

ARTICLE III.

The Influence of Air upon Fruits.

M. Bérard, in his experiments on the effect of air upon fruits, placed green fruits of various kinds in well-corked flasks, or under bell-glasses inverted over mercury, and exposed them to a strong light. After the fruit had remained within these glasses twenty-four hours, an analysis of the air, of which the volume was from seven to eight times greater than that of the fruit, always presented him with the following results.

Carbonic acid	4
Oxygen	16.8
Azote	79.2
	100

In every instance, a portion of oxygen had disappeared, and had been replaced by a nearly equal quantity of carbonic acid. The quantity of carbonic acid given out, is often found to be a little less than that of the oxygen absorbed. By diminishing the quantity of air in which the fruits are exposed, the oxygen may be almost wholly absorbed. Experiments made with glasses, of which the fruits occupied one third of the capacity, presented the following results.

Carbonic acid	18.52
Oxygen	1.96
Azote	79.52
	100

It appears to be proved by these experiments, that fruits exposed to the action of air in a well-lighted place, and under the successive influences of day and night, absorb oxygen, which combines with the carbon of the fruits, and forms a volume of carbonic acid nearly equal to that of the oxygen imbibed.

The same changes took place when the apparatus was exposed to the rays of the sun, but with this difference, that the decomposition of the air was more prompt and more complete in the direct rays of the sun, than merely in daylight, or in the darkness of night.

Some almonds exposed to the sun from nine o'clock in the morning till four in the afternoon, changed the air of a bell-glass as follows:

Carbonic acid	15.74
Oxygen	5.65
Azote	78.61
	100

In this instance it appears, that, besides the carbonic acid formed by the union of the oxygen of the atmosphere with the carbon of the fruit, the fruit itself furnished a small quantity; whence M. Bérard concluded, that fruits affect the air very differently from flowers. Instead of changing, as the leaves do, when acted upon by the solar rays, the carbonic acid of the atmosphere into carbon and oxygen; the fruits unite the oxygen of the atmosphere with their own carbon, for the formation of carbonic acid; so that, in the sun, as in the shade, they absorb oxygen, and transpire carbonic acid.

M. Bérard obtained the same results when his experiments were performed upon fruits still adhering to the tree, and which were in full vegetation.

The ripening of fruits appeared to M. Bérard to be performed by the subtraction of their carbon, through the assistance of the oxygen of the air by which they were surrounded. When this subtraction is in any way prevented, the fruit withers and dies.

When a vacuum is produced in receivers containing the fruits; or when these fruits are surrounded by an atmosphere of hydrogen, of azote, or of carbonic acid, they disengage at first a small quantity of carbonic acid, but the quantity of it diminishes sensibly, and ceases altogether towards the third or fourth day.

In every instance, green fruits remained a long time without undergoing any change; they made no advance towards ripening, but continued stationary; resuming, however, their natural action, when, at the end of several days, they were placed in a situation in which they could absorb oxygen, and transpire carbonic acid.

When fruits are ripe they continue to absorb oxygen, and to form carbonic acid by the union of it with a portion of their carbon; they likewise furnish a great quantity of this acid, which is produced by the combination of their own elements.

The observations made by M. Bérard upon fruits, at different stages of maturity, show that the same principles are found in them at various periods, but combined in unlike proportions. I will here cite only one of these analyses.

	Apricots, very green.	More advanced.	Ripe.
Animal matter	0.76	0.34	0.17
Green coloring matter	0.04	0.03	0.10
Woody substance	3.61	2.53	1.86
Gum	4.10	4.47	5.12
Sugar	*some appearances.*	8.64	16.48
Malic acid	2.10	2.30	1.80
Lime	*a little.*	*a little.*	*a little.*
Water	89.39	84.49	47.84

Cherries, currants, prunes, peaches, &c., analyzed, both when green and when ripe, presented the same results, with some slight difference in the products.

By the process of ripening the animal matter, woody substances, malic acid, and water are diminished, whilst the sugar is considerably increased. This last substance, when extracted from grapes, figs, and peaches, fully ripe, may be partially crystallized; whilst that from apples, pears, currants, cherries, apricots, and prunes, remains liquid and uncrystallizable.

When green fruits, fully grown and ready for ripening, are placed in an atmosphere deprived of oxygen, the process of ripening does not go on; it is, however, only suspended, and will commence when the fruit is replaced in a situation where it can obtain oxygen; unless it has been kept too long in the dis-oxygenated air.

After ripening, fruit undergoes another alteration, which changes its nature; it becomes mouldy or rotten, and in this state gives out great quantities of carbonic acid. The carbon is principally furnished by the woody portion, which turns brown, and by the sugar, the proportion of which is gradually diminished till it finally disappears; whilst the oxygen can reasonably be attributed only to the decomposition of the water. I am the more inclined to believe this assertion, because it may be observed every day, that when fruits are fermenting, or decaying in heaps, a peculiar odor may easily be distinguished in the surrounding atmosphere, approaching to that of some gaseous combinations, especially that of hydrogen with carbon.

M. de Saussure, who repeated the experiments of M. Bérard upon fruits, has deduced from them consequences somewhat different; he believes this to arise from M. Bérard's having enclosed his fruits in jars containing only six or eight times their volume of air; the almost immediate contact of the sides of the receivers, heated by the sun, must necessarily have produced a change in the fruits, by occasioning the commencement of decomposition.

The result of the experiments of M. de Saussure leads to the conclusion, that green fruits exercise the same action upon the air as the leaves do, though with less intensity. Like the leaves, green fruits absorb oxygen during the night, and give out carbonic acid, of which they again absorb a part. Fruits transpire oxygen in the sun; when very green they consume more oxygen in the dark, than when they approach to maturity.

The experiments of M. de Saussure have always been made upon volumes of air, exceeding from thirty to forty times those of the fruits; and by this means the heating action of the sun was much diminished.

The results of the experiments of M. Bérard are all applicable to the ripening of fruits, which was the particular object of his attention; whilst those of M. de Saussure relate chiefly to their growth. The first considers the changes they undergo when detached from the tree; and if he sometimes performed his experiments upon green fruits, their action under his small receivers was like that of dead bodies. The second analyzed the phenomena of their growth; and it is not astonishing, that the two should have obtained different results.

ARTICLE IV.

The Influence of Water upon Nutrition.

WATER influences vegetation not only by the nutritive principles furnished to plants by its decomposition, but by means wholly physical, and which we shall first consider.

The first effect of water upon a soil appropriated to vegetation is, to moisten and divide the earth, and consequently to favor the extension of roots, the introduction of air, and the developement of seeds.

The second is that of conveying to the seed the first aliment required by it, oxygen, which that liquid always holds in solution in a greater or less degree, and which is, as I have already observed, the principal agent in germination.

The third office performed by water is that of dividing the manure applied to the soil, of dissolving some portions of it, and conveying them to the organs of the plants in a state fitted for their digestion and nourishment.

All kinds of water are not equally suitable for this purpose; rain water, which is the purest and contains the most air of any, is also the best for supplying the wants of plants. Generally speaking, those streams which have their rise in granitic or primitive calcareous mountains, are favorable to vegetation; but it is necessary that they should flow through soils free from metallic salts or earths; and that they should have traversed, before being used in agriculture, a sufficient space to have become impregnated with a due portion of atmospheric air.

Streams may not be pure, and yet may be very serviceable for watering the soil, especially if they carry, or hold in solution, certain salts favorable to plants, and some animal or vegetable substances. In this case they possess double virtue, and produce double effect.

Waters may be divided into three classes; the first comprehending those that are charged with animal matter; the second, those which hold in solution some of the principles of vegetables; and the third, the pure waters, or those which contain salts in but small quantities.

The waters of the first class are the most active; and amongst them, those which are loaded with the sweat of wool, or with the ammoniacal combinations arising from the fermentation of powdered bones, of shavings of horn, or fragments of wool, hold the first rank. When employed in their dry state, as manures, these substances produce their effects very slowly, but exercise a much more energetic action when, during decomposition by putrefaction, their products are absorbed by water as fast as formed, and immediately conveyed to the plants. The soft, fleshy, or liquid portions of animal substance do not produce so lasting an effect; their decomposition is too rapid for their action to be continued for any length of time.

The waters of the second class, those that are charged with some of the products of vegetation, either natural or arising from decomposition, form very good manures.

When plants have yielded to water all their soluble portions, the subsequent decomposition of their insoluble fibres furnishes new soluble products, which serve for nourishment; water imbibes these as fast as they are formed, and transmits them to the plants with which it comes in contact. In this manner dead plants supply food to the living, and all the elements composing the first are found differently combined in the last.

When natural vegetable products, or those arising from decomposition, are mixed with, or dissolved in urine or the other animal fluids which are charged with salts, the effect upon vegetation is much increased, because, in addition to exciting the digestive organs of plants, these salts dissolve some substances which could not in their original state penetrate into these organs. It is for this reason that cakes of rape seed, wild mustard, and nuts, used in the manner mentioned above, afford the best manure known.

The waters constituting the third class, hold in solution some salts; these salts may be considered as performing several offices in the act of vegetation; they stimulate the vitality of plants, and increase the activity of their powers; they produce, in fact, upon plants, the same effects as those produced upon the human body by the use of such condiments as marine salt, and salt-petre. Salts of the same nature as those contained in waters of the third class, always produce good effects upon the soil to which they are applied, either by sprinkling the ground with them, or combining them with barn-yard manure.

Though these salts are useful to vegetation, it is necessary to guard against using them in excessive portions, as they then dry up and destroy the plants. Lands which have been long overflowed by the sea, refuse to yield any thing to cultivation till they have, by the repeated action of fresh water, been freed from the salt with which they had become impregnated.

Some of the salts that are conveyed into plants by water, exert an influence over them independent of their stimulating power; being decomposed within their organs, and serving, by the assimilation of their constituent principles, as nourishment to the plants. The greater part of the salts derived from the animal or vegetable kingdoms, are of this description.

Having considered water as a mechanical power, and as a vehicle for the conveyance of food to plants, it remains for me to make known its direct influence upon them.

M. de Saussure has proved, by experiment, that plants decompose water, and appropriate to their own uses the hydrogen and the oxygen contained in it; but this assimilation is very trifling, if they cannot at the same time absorb carbonic acid. The small increase of weight gained by a plant in an atmosphere containing only oxygen, sufficiently verifies this.

Dead plants which ferment when secluded from oxygen, give out some carbonic acid; but this only proves the combination between the carbon and oxygen contained in vegetable products.

Next to carbon, the most abundant principle in plants is hydrogen; which appears to be furnished, in a great measure, by their power of decomposing water. Hydrogen can be obtained from plants by distillation, but in the decomposition of dead vegetables, it unites either with the oxygen of the air to form water, or it is exhaled in union with carbon as carburetted hydrogen.

ARTICLE V.

Of the Effects of the Nourishment of Plants upon the Soil.

It appears to be clearly proved, that plants imbibe from water and the atmosphere only carbon, oxygen, and hydrogen; but analysis shows us that, independently of these principles and the products arising from their combinations, plants contain azote and some earthy and saline substances, which cannot be produced by either of the three elements mentioned above. It remains then for us to inquire, in what manner these substances have been introduced into plants.

Azote, which is found in the albumen, the gelatine, and the green coloring matter, is not sensibly drawn from the atmosphere, though it constitutes $\frac{4}{5}$ of it, but passes in with oxygen in the water imbibed by plants, and, like that, is separated in their organs.

The earths which are insoluble in water, but which are mixed with, or suspended in that fluid, are not absorbed in large quantities by the pores of plants, but may be conveyed into them by the aid of some chymical agents, as the acids, the alkalies, &c. Besides, if we observe attentively, we shall find that these substances do not abound in plants; and we can easily conceive, that the little they do contain, might, in a state of extreme division, be introduced by water.

There are some plants that fasten themselves and grow upon the most barren rocks, deriving from the surrounding air, and from rains, all the nourishment required by them; of this number are the mosses, the lichens, and the fleshy plants. Their growth is slow, their transpiration almost nothing, and their color remains nearly the same all the year round; so that they constantly absorb water and carbonic acid, and assimilate their constituent principles.

The soil is always exhausted, in a greater or less degree, by the plants it produces; and much more by those that are annual, than by those that are perennial. Air and water alone do not afford a sufficient degree of nourishment to plants, for when they have been made to grow in well washed sand, watered with distilled water, though they have flowered, their fruits did not arrive at maturity. Experiments to this effect have been made by Messrs. Giobert, Hassenfratz, de Saussure, &c.

Those annual plants which transpire most, generally exhaust the soil in the greatest degree. Peas, beans, and buckwheat, though they have succulent stalks, exhaust it least, because they transpire but little.

When annual plants are cut at the time of flowering, they do not exhaust the soil, as their succulent roots furnish materials for replacing the loss occasioned by their growth; but after having produced their fruits, the soil derives but little advantage from the dry fibres which are the only remains of their stalks and roots.

During fructification, plants absorb but little nourishment from the soil; the supply necessary to the formation of the seed is furnished by those juices which already exist in the roots and stalks, and this occasions them to become dry and exhausted, so that, when the fruit is perfected, the roots and stalks consist only of woody fibre. It is necessary that this fact should be known, in order that too late mowing of meadows, whether natural or artificial, may be avoided. The most favorable period for cutting grass is that of its flowering; if the operation be postponed till the seed is formed, two great disadvantages will arise; the first is, that the fodder obtained will have parted with the greater portion of its nutritive qualities; and the second, that the plants, having fulfilled all the laws of their nature, by providing for their reproduction, cannot flourish again with vigor during the same year. In support of this doctrine, I will mention one well-known fact, which is, that meadows mown before fructification afford the most abundant harvests, and the greatest number of them, as they may be mown several times in a year. The perennial plants which serve as fodder, may by this means be preserved for several years in a state of reproduction, but if mown after the formation of seed, the plants are weakened and the reproduction is lessened.

All farmers know, that when they subject to tillage a piece of artificial grass land, which has for several years been constantly mown at the time of flowering, it will yield several harvests without any dressing; but if the grass has been left to go to seed, it will be necessary to supply the earth with manure before it will yield a good return. As those plants that are cut at the time of flowering do not exhaust the soil so much as those that remain for seed, the belief has arisen amongst farmers, that before the period of fructification, they are nourished by the constituent principles of the surrounding air and water; but that during the time of the formation of the seed, their support is almost wholly derived from the earth. But this opinion will not hold in regard to all plants; lettuce, turnips, tobacco, woad, endive, cabbages, and onions exhaust the soil greatly, though they are gathered before producing seed. Potatoes, though they produce but few seeds, impoverish land more than almost any other vegetable. Plants raised in a nursery, and afterwards transplanted, exhaust the soil in which they spring, more than the one in which they complete their growth.

Thus we see, that during the whole time of their vegetation, plants derive their nourishment from the air, and from the substances contained in the earth; but if they are mown at the time of flowering, they leave in the soil their roots and portions of their stalks, which restore to the earth nearly as much as they have received from it; whilst, if they remain uncut till they have completed their course, they return little or nothing to the soil to compensate it for the nourishment they have received from it.

It is well known to farmers, that ploughing in a green crop of any kind whatever, prepares the soil for producing well without any other manure; since, by this process, all that the soil has yielded is returned to it, with some additions, resulting from the decomposed principles of air and water, which are contained in the plants.

In order fully to understand this doctrine, which appears to me of great importance to agriculture, it is necessary to consider the successive changes which take place in annual plants during their growth; first, they produce green leaves, which, by coming in contact with the air, receive from it the principles of which I have spoken; subsequently the stalks increase in size and number, and are covered with numerous leaves, which absorb from the atmosphere a degree of nourishment suited to the increasing wants of the plants; the strength, fullness, and depth of hue of the leaves and the stalks, particularly of the latter, increase in proportion to the richness of the soil.

This state continues till after the period of flowering, when a change, worthy of note, takes place ; the roots dry up, the stalks wither and change their color; and when fructification is at length completed, both roots and stalks have become mere skeletons, which answer but little purpose either for nourishing animals or manuring earth. During this period of vegetation what becomes of the juices that were so abundant in the roots and stalks? They have been consumed by the formation of the seeds. It is undoubtedly the case that plants still continue during fructification to absorb some portion of their nourishment from the air and soil ; and this assists in the formation of their seeds ; but by far the greatest share of the formation of these is owing to the deposits contained in the organs of the plants.

The same holds true of perennial plants ; and it may be observed, that when a tree produces fruit too abundantly it becomes exhausted and dried, and bears only that which is small and misshapen. The difference between annual and perennial plants is, that the former die as soon as the process of fructification is completed ; whilst the latter preserve their leaves green and their roots fresh, for the purpose of absorbing new portions of nourishment, to be deposited in their vessels for food when the returning warmth of spring shall cause them to require it.

M. Matthieu de Dombasle, one of our most enlightened agriculturists, has confirmed by experiments the doctrine I have here advanced. On the 26th of June, 1820, at the time of flowering, he selected, within a small space, forty wheat plants of equal size and strength, each having three stalks bearing heads ; he pulled twenty of the plants with all their roots, and left the rest to complete their fructification. Having carefully freed from earth the roots of those he had taken up, he cut the stalks two inches above the base, and dried separately the roots, and the stalks surmounted by their heads.

The roots and the portion of the stalks remaining with them weighed,	grains	657
The stalks, heads, and leaves,	"	1946.5
	Total	2603.5

On the 28th of August, the time of harvest, he plucked up the twenty plants which had been left for seed, separating the roots, and cutting the stalks as of the first; of these the weight was as follows,

	Grains.
Roots	419.53
Straw, husks, and beards	1318.75
Grain	1025.69
Total	2763.97

During these two months, the roots and the portions of stalks adhering to them had lost	237.52
The stalks, head, and leaves had lost	624.67
Total loss	862.19

But as the seed weighed 1025.69 grains, the whole had increased in weight 160.47 grains, Troy. From this experiment we may conclude, that the juices contained in plants, at the time of flowering, contribute to the formation of the grain in the proportion of $\frac{862.19}{1025.97}$, and that the excess of the weight of the grain, which is $\frac{160.47}{1025.97}$, arises from the nourishment which the plant absorbs from the air or soil, during the two months of fructification.

If the wheat is mown when in blossom, it leaves in the earth, to be converted into manure, a quarter part of the weight of the plant; but when it is reaped after having come to maturity, there remains only one seventh; and this last residue is worthless as manure in comparison with the first; this contains almost nothing but carbon, whilst that is rich in juices and in decomposable matter. Thus we see that those plants which form seeds exhaust the soil most, because for all they have received they return nothing but their dry roots and stalks; whilst those that are cut when green give back with their roots and stalks what they have drawn from the soil, and a part of that which they have drawn from the atmosphere.

The nutritive principles contained in the soil pass into plants only in a state of solution, or of extreme division in water. Healthy plants absorb from preference those salts that are most congenial to them; but if waters be charged with salts unsuited to their natures, they absorb the fluid and reject the salts till the water becomes thickened by them.

There are some salts which enter naturally into the composition of certain plants; the pellitory and nettle, for instance, which grow upon the borders of the sea, contain muriate or sulphate of soda; these vegetables, transported into other soils, afford no vestige of these salts, and their growth is less vigorous. M. le Marquis de Bullion has proved that the turnsol, raised in earth containing no nitre, does not, upon analysis, afford a vestige of any; but that plants of the same kind, raised in the same soil, but watered with a solution of nitrate of potash, are charged with that salt.

Generally speaking, a superabundance of salts, especially if they be of kinds very soluble in water, injures vegetation: this is particularly the case when the salts are not such as enter naturally into the plants, amongst the number of their constituent principles. Salts of foreign natures cannot be useful, excepting as they may serve, in very small quantities, to excite and stimulate the organs of plants. The great value of sulphate of lime as a manure, is owing to its insolubility, which allows water to contain but a very small portion of it at once; so that it passes into plants very gradually, and thus its effects are prolonged for several years; till, as I have before observed, the soil is exhausted of it.

The quantity and quality of the salts contained in plants may be ascertained by an analysis of the ashes arising from burning them in a dry state. It may not be useless to mention here some facts which may throw light upon this subject.

Kirwan and Ruckers have proved, that an equal weight of herbaceous plants furnishes more ashes than of ligneous plants. M. Pertuis has found, that the trunks of trees afford less ashes than the branches, and these last less than the leaves. Evergreens yield less ashes than trees and shrubs that shed their leaves in autumn. On the other hand, Hales and Bonnet have observed, that the perspiration of herbaceous is greater than that of ligneous plants, and that that of evergreens is less than that of plants which shed their foliage. These circumstances may explain why some plants afford more ashes than others. The water which is evaporated by transpiration deposits in the cells of the plant the salts which it had held in solution, and is replaced by a new quantity, which is in its turn thrown out, leaving behind it an additional portion of salts; so that those plants, and those portions of the same plant, which transpire most, must necessarily contain the greatest quantity of salts.

The salts and earths contained in plants are of the same nature as those existing in the soil in which they grow, but not, according to analysis, in the same proportions; because the plant absorbs more or less of them according to its own nature and their solubility. It cannot, however, be strictly said, that all the salts contained in plants existed previously in the soil, as some neutral salts are evidently formed within their organs; such are those of which the acid is known to us, and particularly those that contain in their composition a vegetable principle: of this sort are the acetates, the malates, and the citrates. The salts do not exist after the burning of the plant, because their acid is decomposed by the action of fire, and there remains only their base, which is usually potash or lime; but an analysis of the plant "by *the wet way*" gives proof of their existence.

It is even possible in some cases to follow the formation of the acid, by observing the progress of vegetation, and the changes produced in its products. Of this I will mention one example. Beets gathered late in autumn, in the north of France, do not yield the same principles as those gathered at the same period in the south of France; the first contain sugar, the second salt-petre. According to the experiments carefully made by M. Darracq in the department of Landes, the beet roots of the south yield as much sugar in the month of August and the earlier part of September, as those of the north; this sugar then is replaced by salt-petre, of which the acid is formed during the progress of vegetation. It has been observed, that beets containing sugar frequently underwent a change during the winter, by which the sugar entirely disappeared, and was replaced by salt-petre; in this case we can almost follow with the eye the process of decomposition. The juice of beets in which the change has commenced, when thrown into the boilers, becomes covered with a thick, white foam, which gives out a reddish vapor of nitrous gas: in this state the labor of extracting sugar becomes very difficult; the sugar crystallizes badly, and the proportion of molasses is very great. It may be seen clearly, that in this state oxygen is already united in the beets with azote, and that only an additional portion, which would be gained during the progress of change in the roots, is wanting for the formation of nitric acid; this, combined with the potash, which is contained in these roots in the proportion of $\frac{1}{100}$ of its weight, would produce salt-petre.

If we observe a plant during the various stages of its vegetation, we shall perceive at these different periods very remarkable differences in the odor, taste, consistency, &c.; from this circumstance we must suppose that it forms new products, new combinations, and consequently new salts.

The alkaline salts are the most abundant in green herbaceous plants. M. de Saussure has observed, that the ashes of young plants that grew upon a poor soil contained at least $\frac{3}{4}$ of their weight of alkaline salts, and that those of leaves of trees which grew from their buds contained at least $\frac{1}{2}$.

The proportion of alkaline salts diminishes in proportion as the plants advance in age: this remark applies equally to annual plants and to the leaves of those trees that shed their foliage in autumn. The ashes of seeds contain a greater proportion of alkaline salts, than those of the plants that produced them.

These facts are very important to those who are engaged in the manufacture of salts furnished by the combustion of vegetable substances; since they show clearly that it cannot be equally advantageous to them to consume all sorts of plants, nor at all periods of their growth.

Next to the alkaline salts, the earthy phosphates of lime and magnesia are the most abundant in plants, and, like the first, these diminish in quantity in proportion to the age of the plant. Plants also contain, but in very small proportions, silica, and some metallic oxides, especially those of iron.

ARTICLE VI.

The Changes produced in Plants by Nourishment, resumed.

Plants are principally nourished through their leaves and roots: the first absorb from the atmosphere oxygen, carbonic acid, and water; and the second receive from the soil the oxygen and carbonic acid contained in it in a free state, or dissolved in water, and also the juices and salts which are mixed with the earth.

Water appears to be the necessary vehicle of nearly all the nutritive portions of the soil; so that it not only serves to nourish plants, by yielding to them the elements of which it is itself composed, but it conveys into their internal organs all the substances which can serve them as food.

The substances which chiefly afford nourishment to plants, present in their composition only carbon, hydrogen, and oxygen; the numerous products formed in the course of vegetation, do not upon analysis furnish any other principles; the salts, the earths, and the metals are generally found in them in very small quantities, and under a very different form from that in which they exist in the soil.

Strictly speaking, the three principles necessary to vegetation are oxygen, carbon, and hydrogen, combined in various proportions; and it is this difference in the proportions which causes the immense variety in the vegetable kingdom: some hundredths more or less of carbon, oxygen, or hydrogen change the character of the body.

The chymist in experimenting upon dead plants produces at pleasure a part of these effects: fermentation and spontaneous decompositions give rise to a great number. But the constant uniformity of the products in the same species of plants, and the analogy existing between those derived from different species of the same genus; their variety in the different organs, and the peculiar compounds, apparently so complicated, of each one of them, form altogether so many phenomena beyond the power of art to explain.

We know the substances received by plants, and those which they reject; we determine by analysis the nature and the composition of the products which they form; but this is the utmost extent of our knowledge. All that passes within the plant is still a mystery, and belongs to the laws of vitality, which modify by their action those physical laws that are known to us.

However, as the laws of vitality governing vegetables are in their application less independent of the physical laws, than those that reign in the animal kingdom, we can even now raise a portion of the veil, and follow at least the progress of the changes, though we can as yet neither produce them nor discover their mode of action.

The germination of seeds and the swelling of buds in the spring, are almost entirely the results of physical laws: oxygen is the only agent necessary to produce them: water and heat are necessary auxiliaries, but they do not in any way enter into the new combinations; they only facilitate the changes that are going on. The oxygen unites with carbon to form carbonic acid gas; by this means the mucilage and starch are reduced to the state of a milky liquor, which serves as the first aliment of the young plant or twig.

As soon as the plant has unfolded its leaves, or the radicles of the seed have penetrated into the soil, the system of nourishment is changed: every part of the plant in contact with the atmosphere gives out carbon during the night, or when in darkness; but the carbonic acid which this forms with oxygen, instead of remaining in the air, as at the period of germination, is absorbed principally by the roots and leaves, and decomposed in the last by the solar rays; the carbon remaining fixed in the plant, whilst the oxygen is exhaled in the form of a gas. Plants are likewise nourished by that aqueous fluid which, constantly existing in the atmosphere in greater or less abundance, is, by the diminished temperature of the air during the night, deposited in the form of dew. The water contained in the soil dissolves the juices of the manures, and transmits them to the plants.

But in order that plants should flourish, it is not sufficient that they have at their disposition all their necessary aliments; it is further requisite, that the elaboration of these be favored by other causes possessing equal influence over vegetation.

I have already remarked, that leaves do not transpire oxygen excepting when exposed to the rays of the sun; so that the carbonic acid remains in the plant during the whole time that the solar rays are hidden. The establishment of this fact enables us to explain many of the most important phenomena of vegetation: we learn from it, why plants that grow in the shade never produce fruits having the same taste, perfume, or texture as those borne by plants of the same kind growing in the sun; and why the various sorts of fodder and green herbs are of bad quality, when the sun has not access to them to facilitate the decomposition of carbonic acid and the elaboration of the nutritive fluids.

Independently of the light of the sun, without which plants cannot flourish, vegetation requires a certain degree of heat; buds generally do not begin to unfold till the atmosphere is at the temperature of from 50° to 54°; and vegetation gains strength in proportion as the heat of the atmosphere increases, provided that at the same time the earth be sufficiently moist for the water to convey to the plants the nourishment it contains, and to furnish to them the means of transpiration. The influence of temperature over vegetation is so marked, that we can see the latter diminish as the heat lessens, and resume its energies as that is augmented. Warmth renders the sap fluid, and quickens its circulation; cold thickens it and rénders it stagnant. If a right degree of atmospheric temperature, the influence of the solar rays, or a suitable quantity of the aqueous fluid be wanting, the growth of plants is retarded. Thus we see it is not enough that plants are abundantly supplied with nourishment; it is necessary that the concoction of it should be favored by agents which concur in causing its digestion.

When the soil is too abundantly provided with manures, especially of kinds that may be easily conveyed into plants by water, their growth may be prodigiously increased; but if the digestive organs and the constant influence of the sun do not concur in elaborating their juices, the result will be, as I have before remarked, a kind of obesity; and none of the products will have either the savor or the odor that they would have acquired if the nourishment had been less abundant and better digested. It is not uncommon for fruits and herbs to yield the odor peculiar to the manure with which they have been nourished, when it has been too abundantly supplied.

The juices circulate in plants, not only with the same regularity of movement that we observe in animals more perfectly organized, but with a degree of force sufficient to carry them into all the organs, that they may receive in each one of them a peculiar elaboration.

The roots absorb fluids from the earth by means of their capillary vessels; but the force with which they are conveyed into the internal organs of the plant, and even into the leaves, where their carbon combines with oxygen, is superior to that of capillary attraction, and the weight of the atmosphere.

The celebrated Hales cut a branch of a vine four or five years old; this he cemented carefully into a glass tube bent in the form of a siphon, filled with mercury; by the force of the ascending sap alone, the mercury rose at the end of some days to 38 inches. M. Mirbel has confirmed this experiment, and added many others of great importance, but which would carry me too far from my subject.

As the sap circulates in plants by the aid of numerous vessels and cells, which have no rectilinear communication, the force with which the sap ascends may be explained by a principle deduced from the experiments of M. de Montgolfier, who has proved, that, by means of a very small force, liquids may be raised to an almost indefinite height, provided the pressure of the column of liquid be destroyed by numerous interceptions or valves.

The force with which the sap ascends is proportioned to the health of the plants, and the abundance of its transpiration: a stalk deprived of its leaves will raise less mercury than one retaining them; and trees having smooth, spongy leaves abounding in exhaling pores, such as the wild quince, the alder, the sycamore, the peach, the cherry, &c., raise it to a much greater height than those of which the leaves are varnished or dry. The beautiful experiments of Hales have verified these results.

All the water imbibed by the different parts of plants, but especially by the roots, is first employed in mixing the juices, and facilitating their circulation; it is then decomposed, and a part of it furnishes hydrogen, so abundant in the products of vegetation, but the greatest portion is evaporated, principally by the leaves, and thus maintains their temperature below that of the atmosphere during the burning heat of summer. Hales observed, that a sun-flower plant transpired by the leaves, in the space of twelve hours, 1 lb. 14 oz. of water.

The cold which begins to make itself felt in autumn, retards the movement of the sap; the fluids become thickened, the solids contracted, the leaves cease to inhale, and the roots no longer absorb nourishment from the soil, and at length the vital functions are suspended. The returning warmth of spring brings renewed life to the organs; the fluids and the solids receive a greater expansion, circulation is restored, and the sap deposited in the vessels during the summer and earlier part of autumn, affords the first nourishment to plants.

The branches of trees that are lopped off in winter, put forth buds and stalks in the spring; a branch of a vine introduced during the winter into a hot-house, vegetated as it would have done in the spring, whilst that portion of it which remained exposed to the cold experienced no change. Plants that have been browsed in autumn, do not put forth so early, nor with so much strength as those of which the roots, and the parts immediately surmounting them, have been preserved by mowing.

All agriculturists have observed, that young trees transplanted in the spring appear to flourish for three or four months, and then die; if when taken up they have examined their roots, they have almost invariably found that they presented no appearance of having increased; which proves that vegetation is carried on in the spring by the nourishment provided, and deposited in plants before the fall of the leaves.

The difference which exists in the vegetation of the same branch, one end of which is placed in the earth, and the other rising above it, must strike every observer. The part which is planted in the soil, sends forth roots, whilst that which rises into the air produces leaves; and if any part of the root be uncovered, so as to come in contact with the air, it produces stalks and leaves; whilst that which remains beneath the soil continues to grow as the root of them. All parts of plants then are organized by their growth in such a manner, as shall enable them, most conveniently, to imbibe at the same time their nourishment from the soil and from the atmosphere.

It is in the power of art to influence the flow of the sap, nearly at will. When the nourishment afforded by the earth is too abundant, it is but imperfectly digested, and is exclusively employed in the growth of the plants; a tree in this case produces neither flowers nor fruit, but expends all its strength in leaves and wood. To remedy this superabundance of sap, some of the roots may be separated; or what is still better, incisions may be made in the bark of the tree to cause the escape of a portion of the sap.

If it be wished to facilitate the growth of the fruit, a portion of the branches may be pruned, and part of the fruit be plucked off; in this way a greater quantity of sap may be supplied to the fruit that remains; tight ligatures upon the branches, and incisions surrounding them through the whole thickness of the bark, produce the same effect. The pruning of fruit trees is principally designed to limit the production of fruit to the quantity that can be properly nourished by the plant. The grafting which is practised upon trees of analogous species, only presents to the juices of the wild tree an organic tissue different from its own; in the cells of which the juices receive a peculiar elaboration, which changes the nature of their products.

It is not by an analysis of plants, nor by the proportion of their constituent principles, which can be extracted by water, that we can judge of the nutritive quality of vegetables, or other alimentary substances. I have already proved, that a nutritive substance, deprived of all its soluble parts by water, is capable, in the progress of its decomposition, of forming new and soluble compounds. It is only by experiments, and by the effects of this or that kind of food upon animals, that we can ascertain the differences existing between various nutritive bodies.

The digestive juices of the stomachs of animals and the organs of plants animated by vital powers, of which we are ignorant, have also their chymistry, with which we are unacquainted, and of which we can understand only the results. It is surely erroneous to pretend to determine the quantity of nourishment, by that portion which can be extracted from any article of food by water; but upon this principle Davy has represented the nutritive virtue of beets by the number of 136, and that of carrots by 98; whilst M. Thayer has by his experiments estimated that of the first to be 57, and of the last 98. Upon the same principle Davy has valued the effects of linseed cakes at 151, compared with those of beets as 136; while it has been proved that 70 lb. of beets are hardly equivalent in nourishment to 10 lb. of linseed cakes.

In order to estimate the nutritive merits of any substance, it is necessary to have less regard to its chymical character, than to the nature of the animal to be nourished by it: one is disgusted by that which pleases another; and this will decompose what that will reject; it is only by observation that we can decide.

These principles are still less applicable to the nourishment of plants, than of animals; because of the first it is necessary that their food should be presented to them, and in a state of solution or mixture; whilst the last seek theirs where it may be found, and make choice of such as is suitable for them; but in both cases the nutritive virtues of the food can be estimated only by the results of its elaboration in the digestive organs, and by the effects produced on the economy of the animal or vegetable. It should besides be remembered, that the nutritive qualities of the various products of vegetation depend less upon their weight, than their kind; and that a substance may be insoluble in water, which may, when acted upon by the gastric juices, become excellent food.

CHAPTER VI.

IMPROVEMENT OF THE SOIL.

To improve the soil is to render it more suited to vegetation by ameliorating the nature of the earth. All then which tends to dispose a soil favorably towards plants, in connection with the action which is exercised upon them by air, water, temperature, manures, &c., may be justly termed improvement. Thus, before undertaking to improve a soil, it is necessary to be acquainted with its qualities, and particularly with its defects, that we may apply to it the means of improvement it requires.

This preliminary knowledge of the defects of a soil implies a second, which is that of all the agents which can be employed in its improvement: the correction of known faults can only be performed by means of substances possessing opposite qualities.

As in the term improvement is implied all which can tend to ameliorate a soil, it necessarily has a very extensive signification; it comprehends operations purely mechanical, and the use of those earthy and nutritive mixtures, which are produced by art; it likewise comprises all the means which can be employed to direct advantageously the action of air, water, heat, &c. It is in all these relations, that it is necessary to consider the great art of improvement.

The best earths produce but little, if they be not stirred by the spade, the hoe, or the plough. This operation divides and softens the earth, brings to the surface the manures of all kinds, which the rains had caused to sink below it; facilitates the spreading of the roots, mixes the dung with the earth, and renders its action more equal; it destroys weeds, and causes them to serve as manure; and it frees the soil from vermin, which would otherwise multiply in it to the destruction of the harvests.

This operation is performed upon all soils of what kind soever; it forms the very basis of agriculture; without it there can be no harvest. The tillage by the hoe is much more perfect than that by the plough, but the spade is a still more efficacious implement. The plough divides and turns the soil with less exactness than either of the others; and notwithstanding the crossed and multiplied furrows, there will be some portions of the intervals and intersections, where the soil will remain untouched; but as tillage by the plough is the least costly, and the most expeditious, it has generally received the preference.

I know a little village in Touraine, between the Cher and the Loire, where all the lands are cultivated by the spade, and their produce is always double that of any in the neighbourhood; the inhabitants have become rich, and the soil has doubled in value. In Bremont, between Loches and Chinon, they employ no other means of cultivating a very fertile soil; but this method can be used only on small estates, or in a country where labor is very abundant and to be procured at a low price: I do not doubt, however, that there are some localities where it could be conducted with profit, if it should be employed from time to time to ameliorate successive portions of land, especially those that have been used for the cultivation of such plants as have long roots.

In the alluvial soils formed by the deposits of the Loire, between Tours and Blois, the farmer reaps from his land a harvest of corn, and afterwards lets it to persons, who turn it to the depth of a foot, with spades, and raise upon it leguminous plants.

From the effects produced by this kind of tillage, we may perceive, that it cannot be employed equally in all soils, or indifferently at all seasons, nor be always carried to the same depth. A light, porous, calcareous, or sandy soil requires less tilling than that which is compact and argillaceous; and this last requires to be stirred more deeply than the first, because otherwise the roots cannot penetrate it and fasten themselves in it; neither can the air gain access to deposit upon them its kindly moisture.

Calcareous, sandy, and siliceous soils may be tilled at any time, whilst the argillaceous soils are in a fit state for the plough only at certain seasons, which must be eagerly seized upon by the farmer; the action of the plough upon these lands immediately after rain, only leaves marks in the mud; and if they be allowed to remain till they are thoroughly dry, they become impenetrable by it; the interval between these two periods is the time most favorable for tilling.

The best tilling does not always prepare soils entirely for cultivation; some are not sufficiently divided or crumbled; others are not sufficiently levelled, and it is only by the assistance of the harrow, or the roller, that the labor of tillage can be completed. By dragging the harrow in all directions over a newly ploughed field, the clods left by the plough are turned over, the uprooted weeds are carried off, and a more equal division is given to all parts of the soil. The strength and weight of the harrow must be in proportion to the resistance offered by the nature of the soil. The harrow can be employed advantageously in opening the soil of artificial meadows, especially those of clover, when the surface has become a crust impenetrable by air or water; the operation of harrowing, in this case, should be performed early in the spring of every other year, or immediately after having cut the first crop of fodder; by this means, many plants injurious to the soil are destroyed, and meadows are restored, which would have been constantly deteriorating. I have practised harrowing fields of grain, early in the spring, with great success, and have found the harvests from them uniformly much finer, than from those that had not been harrowed; but it was necessary to pay attention to having the harrows very light, and made with wooden teeth.

The roller I have found to produce an excellent effect after the seed was covered; it unites and levels the surface of the ground, and is particularly useful for porous and light soils, and for those earths of which the constituent particles are fine and light. If such soils have not received a suitable degree of firmness from the roller, high winds and rains are apt to carry off the upper layer, and to leave bare the roots of the plants. Another advantage arising from the application of the roller is, that the soil which has been subjected to it, presents fewer obstacles to the use of the scythe, or of the sickle.

When frosts have bound up the soil, and it has been again set free by thaws, the roots are left almost without support, as the earth scarcely adheres to them : the roller, applied to lands as soon as they are firm enough to admit of its being passed over them, is very useful, as it reunites the earth to the roots, and repairs the injury done by the frosts and thaws.

A judgment of the mixture necessary for amending a soil, can be formed only from a perfect knowledge of its defects.

A soil in the composition of which the best earths are united, does not need to be improved by the addition of new earthy principles : good tillage and the application of manure are sufficient to render it fertile : but that soil in which any one of the earths predominates to such a degree, as to give a character to the whole mass, requires to be corrected by the admixture of substances possessing opposite qualities. I shall distinguish soils as argillaceous, calcareous, siliceous, and sandy : these divisions seem to comprise all those requiring to be amended ; and the quality of the earth predominating in each, indicates sufficiently the kind of improvement suitable to it.

An argillaceous or clayey soil is rendered pasty by rains, and it is hardened and cracked by heat ; it absorbs moisture from the air only on its surface, but it imbibes abundantly the water of rains, and retains it by so strong an affinity, that when the supply is in excess, it remains till it stagnates and causes the roots of plants to decay.

An argillaceous soil is unfavorable to cultivation ; for when it is acted upon by the frost, the water contained in its interstices expands by freezing, and the thaw which sets the earth free, divides it into morsels with which the roots of plants have so little cohesion, that they may be drawn out from it almost without resistance : the roots are at such times in the state of newly planted vegetables ; they have need of being established, of being fixed to, and united with the soil, in order to vegetate. If in this state a root be attacked by a new frost, it dies ; for not being protected by the close adhesion of the soil, the cold acts upon it, as if it were exposed defenceless upon the surface : it is this which renders alternate frosts and thaws more injurious to fields of grain, and to artificial meadows, than the severest cold which continues till spring. It is to obviate this evil resulting from a second freezing, that I propose levelling the earth by the roller, after the first thaw.

These defects, more marked in argillaceous soils than in others, require to be amended; every thing which will tend to soften the earth, to render it more light and porous, and to facilitate the passage of water through it, is perfectly adapted to this kind of soil: thus the mixture of earths, and of calcareous sands, broken shells, chalks, and lean marl; deep and frequent ploughing; the turning in of green crops; the use of hot manures, such as the dung, fresh from the barn-yard, of sheep and horses, that of pigeons and fowls, *poudrette*, and the salts, are so many means which may be made to concur in the improvement of argillaceous soils.

I have had opportunities of seeing many soils possessing the same faults as the argillaceous, but not owing to the excess of that earth; for by mixing a portion of the soils in water, I satisfied myself that there was not contained in them any coarse sand; so that the whole was formed by a union of particles so minutely divided as to present no consistency in the mass; but forming a paste with water, and cracking when that liquid was evaporated. The only difference between the argillaceous soils and these is, that the latter when dried do not possess the hardness of the former, but on the contrary fall, under the pressure of the hand, into a nearly impalpable powder. The state of these soils is owing to their having been exhausted by long cultivation: some of the kind which I have owned, I have been able to restore to fertility by applying a portion of sandy marl containing $\frac{42}{100}$ of calcareous sand.

Calcareous soils possess properties entirely opposite to those of the argillaceous soils; the rains filtrate easily through them, and they throw off moisture readily by evaporation; the air can penetrate them, to deposit amongst their particles the moisture with which it is charged: and this, especially in hot climates, conduces greatly to their fertility. The tillage of these soils is always easy; and as they are light and porous, provided they have sufficient depth, roots spread in them easily. Though, from their character, these soils do not require so much amendment as those that are argillaceous, they may still be improved; especially by giving to them the power of retaining water for a longer time, that they may thus be better able to supply the wants of plants: for this purpose, it is sufficient to add to them some fat marl, or, for want of that, calcined clay. These soils, being naturally warm, require the fresh dung of neat cattle; the unctuous manures are best adapted to them.

Sand incorporated with finely divided calcareous earth, forms an excellent means of amendment, especially if it be combined with clay or fat marl. I have likewise seen the rich mud drawn from rivers, used with great success in improving calcareous soils.

There is a great resemblance in many respects between sandy and siliceous soils: both are formed, generally, by the alluvion of rivers; both of them are nearly barren when they contain no other principles; and both of them form the base of very good soils, if they are suitably amended.

When these soils are formed by the inundations of rivers, or by streams that have taken new channels, they are for some time destitute of fertility; but the successive swellings of the rivers deposit a rich mud, which becomes at length incorporated with the first layer; and when the whole is well united, an excellent soil is formed. This mud is very fertilizing, from its containing the remains of all those animal and vegetable substances, which muddy waters carry with them in their overflowings. When these soils are left to themselves, we see plants springing up on them spontaneously, from the seeds deposited by the waters which conveyed them there.

Soils of this kind rarely require manuring: successive inundations constantly renew their fertility: their level is raised by the accumulation of deposits, till at length they are not subject to being overflowed, excepting when the rivers rise unusually high; and in those cases the large pebbles, which never float upon the surface of water, cannot be deposited upon them. These lands, so valuable for agriculture, do not offer much resistance to the rapid current of great inundations, which often carry them off; nor to the masses of ice, which at the breaking up of the frosts gully and furrow them. I believe I ought here to devote a few lines to pointing out some methods for preserving these valuable lands from such accidents: it is of more consequence to preserve property than to improve it.

In order to prevent the evils of which I have just spoken, it is customary to surround lands of this kind with plantations of trees; but trees of a large size cannot take root firmly in a sandy and easily disturbed soil. The winds are generally very violent in those valleys through which large rivers flow; and these, by the violent motion which they give to the branches, twisting them in every direction, loosen the roots; and the earth being continually disturbed, the water penetrates in, and softens it, so that when an overflow of the river happens, the breaches thus made in the soil lessen its powers of resistance to the flood.

If we observe carefully the action of currents upon the great trees surrounding lands situated upon the banks of a stream or river, or upon an island lying in the course of one, we shall be convinced, that, so far from preserving, they facilitate the destruction of property; for as the trunks oppose an invincible resistance to the force of the current, it is divided, and, encircling them, it meets again, having formed a complete trench in the soil. Thus, though large trees may be useful for turning aside masses of ice, and preventing the land from being much injured by them; yet instead of preserving it from the ravages of a rapid current, they become powerful auxiliaries to its destructive action.

Flexible shrubs are undoubtedly preferable to large trees; their roots bind the soil; their branches lie upon the surface of the earth, and preserve it from injury during floods; but these shrubs do not present any resistance to the ice when the rivers are breaking up; they cannot turn aside the masses of it, and force them to remain in the bed of the river, that they may not furrow the meadow or field. It is necessary then to unite the resistance offered by trees with that of flexible shrubs: in order to do this, it is necessary to plant willows or poplars on the extremity of the banks, at the distance of seven or eight feet apart; the heads of these may be cut off some feet above the height to which the highest floods ever reach; the water willows or osiers may be planted all along upon the shelf or slope of the land, and from twenty-five to thirty feet inward. In a few years there will be nothing to fear from floods or ice upon land defended in this way; and a considerable revenue will arise from the pruning of the trees, and the clippings of the osiers.

After having placed the land out of danger from inundations, the neighbourhood of a river opens sources of profit that are very simple, and may be taken advantage of at a slight expense. I have heretofore remarked, that the mud of rivers is of great use as an amender of soils, and that when employed upon alluvial lands it supersedes the necessity of applying to them other manures; it is then advisable, in overflowings, to retain that mud, and that only, which possesses the greatest power of fertilization.

When the overflow of a stream commences by inundating that portion of land which lies highest up the current, it spreads with great rapidity over the whole extent of it, furrowing its surface, and carrying beyond it all the most finely divided mud with which it is loaded; often uprooting crops and washing away the manures which have been deposited during former overflowings; and thus impoverishing instead of enriching the soil. But when the rise of water begins down the current, and the whole tract of land is slowly submerged, till, even to the head, it is under water, the soil receives and retains all the richest and most finely divided mud, as well as the remains of animal and vegetable substances which the stream has in its downward course washed off from other tracts of country, without any injury being sustained either by the harvest or the land. In order to give the desired direction to the current, it is only necessary to raise the head of the land, or that part which lies up the stream, and to plant the bank with osiers.

By these means, I have improved and tripled the value of certain islands belonging to me in the river Loire. These islands, which formerly produced but little, and were constantly receiving injury from the swellings of the river, are now the most productive portions of my estate, for the cultivation of grains and beet roots.

When sandy or siliceous soils are situated at a distance from a river, or are by the height of the banks placed beyond the reach of an overflow, it is necessary to ameliorate them by art; and this must be done by the addition of fat marl, clay, dung, &c. The amendments must be varied according to the nature and fineness of the sand: calcareous sands retain moisture better than siliceous sands.

I have seen some soils formed of beds of large pebbles, which, without the appearance of mould upon the surface, produced very good crops: the layer of pebbles, which was second from the surface, contained earth enough to enable the plants to take root and flourish.

Soils of this kind furnish excellent pasture for sheep, as may be observed on the ancient and immense alluvions of the Durance and the Rhone. The herbage upon these is excellent, and suffers less from drought than elsewhere; being protected from the ill effects of the scorching rays of the sun, by the pebbles lying above its roots.

Rozier made the experiment of covering a part of the soil of his vineyards with pebbles, and found it attended with good effects, especially as it regarded the quantity of wine obtained. One of my friends owned in Paris, near the barrier d'Enfer, an enclosure, of which the soil was so dry and poor, that notwithstanding all the pains he bestowed upon it, he could never make any fruit trees thrive there: in order to amend the soil, he covered it with a layer of good earth, which he mixed with the dry sand of the spot; this gave it some degree of fertility; but the heat dried his plantations so much, that he could only preserve them by frequent and very expensive waterings: he at length concluded to cover the surface of the ground with a layer of pebbles, and from that time the trees prospered.

In some countries, recourse is had to fire, as an amender of the soil: this process, called burning, is strongly recommended by some practical farmers, and highly disapproved of by others: both sides rely on the test of their own experience; and both are so sincere in their opinions, that it would be useless to contest the truth of their observations. I can only agree with each of these contradictory opinions, and at the same time make known the cases to which burning is applicable, and those to which it is unsuited, in order to enlighten the agriculturist as to the effect of the operation: he can afterwards make for himself just and rational applications of the theory.

In the process of burning, a layer of from two to four inches in thickness, is removed from the soil in clods: little heaps of combustibles are formed with the broom, thistles, fern, and shrubs that grow upon the spot: these are covered with the clods, and at the end of some days are set on fire; the combustion of them lasts a longer or shorter time. When the whole has become cool, the heaps of ashes are spread over the surface, and thus mixed with the soil.

By this operation the constituent parts of a soil are divided, and rendered less compact; the disposition which a clayey ground has to absorb a great quantity of water, is corrected, and this soil rendered less cohesive and pasty; the inactive vegetable matter contained in it, is converted into manure: the oxidation of its iron is carried to its maximum; and insects and the seeds of injurious plants are destroyed. Hence we perceive that burning belongs to moist, compact soils; it is attended with good effects when the bed of earth is too cohesive, or when it presents veins of blackish oxide of iron: it is suited to nearly all cold and compact lands.

Burning, especially if it be judiciously conducted, completely changes the nature of a soil, and corrects the greater part of its imperfections. I have by this means given to agriculture 120 acres of land reputed sterile, formed almost entirely of a ferruginous and very compact clay: the burning extended to the depth of four inches. For twelve years this land, though not very productive, has afforded me good returns. Its former sterility had procured it the name of the *Jews' heath.*

Burning is hurtful to calcareous and light lands; to soils of which the composition is perfect; and to fertile lands, rich in decomposed animal and vegetable substances.

It is useless to soils purely siliceous, for these can receive no modification from fire.

In some countries it is customary to burn the stubble upon the field; this method, which is only an imperfect mode of burning, is productive of good in two ways; in the first place, it purifies the soil from insects, and from the seeds of noxious plants; and in the second place, it forms a thin layer of carbon, which by its extreme division is capable of being easily absorbed by plants. I believe that even the heat occasioned by the combustion of the stubble and herbs covering the soil, may produce salutary changes in the combinations of the constituent parts.

The results which I obtained from mixing calcined clay with the sand constituting the soil upon a portion of the plain of Sablons, near Paris, has led me to think, that whenever lands of this nature are cultivated, it may be useful to amend them by the same process: in order to do this, clay may be formed into balls by moistening it with water enough to reduce it to a paste; these balls, after having been calcined in a lime-kiln, or the oven of a pottery, may be pounded, and the fragments mixed with the soil. Calcareous, siliceous, and sandy soils may be in this way much improved.

Of all the agents which may be employed as amendments, there is none of which the action is more powerful than that of water: not only does it contribute to the nourishment of the plant by its decomposition, which deposits in the vessels its elementary principles; but it acts still farther by promoting the fermentation of manures, and by conveying into the vegetable organs the juices and salts. Independently of these properties, water dilutes the sap, which has become thickened in the body of the plant, and facilitates its circulation; and likewise furnishes abundantly the means of transpiration. The soil is also softened by water, and thus rendered more permeable by the roots, and by atmospheric air which supplies them with the moisture it contains.

All the excess of water absorbed by plants, is thrown off by transpiration; and this transpiration is always more or less abundant in proportion to the quantity imbibed.

The custom of inundating meadows during winter, preserves them from the effects of hard frosts. Davy ascertained the temperature beneath the bed of ice covering a meadow, and above it: beneath the ice his thermometer stood at 43°; above the ice at 29°. Every one must have observed, that when the surface of a meadow is only partially covered by water during the winter, the herbage upon that part which is left dry, is withered and nearly dead, whilst the rest retains its green hue, and continues to grow.

The character of water used for irrigation, is a thing of some consequence; that of a living stream is the best especially if it have, by a long course, become impregnated with a good quantity of atmospheric air.

Though water is the most active agent in vegetation, it is nevertheless necessary to apply it with reserve and caution: the worst effects are produced by irrigating land so often as to keep the soil constantly in the state of a liquid paste. The first evil arising from such a course is that of increasing the size of the plants to the injury of all their other qualities; for in such a case the fibres of plants become loose; the texture soft and watery; the flowers are inodorous, and the fruits without firmness, taste, or perfume. The second is, that all useful plants which do not require much water, give place to rushes and flags, which change and ruin the soil: in this case the same evil is produced which we seek to destroy in wet lands by the use of soot, gravel, ashes, and other absorbing and saline bodies.

Frequent irrigations are not injurious to poor, light, sandy, or calcareous soils, which have much depth; but they are injurious to rich, compact, argillaceous soils; for in such the noxious plants of which I have just spoken, readily establish themselves.

To ascertain the most favorable times for irrigation, it is necessary to consult the state of the soil, and of the plants; when the earth is deprived of moisture to such a depth that the plants languish, and begin to lose their leaves, the favorable moment has arrived for watering them. If allowed to remain in this state too long, they cease to grow, and hasten to terminate their vegetation by the production of fruits and flowers; but these are always feeble, poor, and incomplete, when produced under such circumstances.

The custom of allowing lands to lie fallow after having produced several harvests, has descended from the remotest antiquity, and is still followed in the greatest part of Europe. It has been thought necessary, that land, after having been exhausted by two or three successive crops, should be allowed to rest, or to remain in fallow during one or two years, in order that it might have time to recover its strength, or productive virtue. The necessity for rest, imposed by nature upon all animals after continued action, undoubtedly gave rise to this practice; and though the supposed analogy between living bodies, and those that are not so, has no rational foundation, yet it has confirmed the custom of fallowing which arose from it.

However, I am far from believing that this was the only cause for the adoption of the method of which I am speaking: I believe that it may be attributed to the want of hands for performing the labor of constant cultivation, or to the impossibility of nourishing a sufficient number of animals to furnish the necessary manures.

The extent to which the cultivation of lands should be carried, ought always to be in proportion to the population to be fed by its products. It is to be presumed, that when the globe had fewer inhabitants, the settlements were made in those spots where the soil was most fertile, and that when these were exhausted, they removed elsewhere; but when property came to be divided and marked out, each cultivator confined his labors to such a portion of land as would supply his wants; so that when it was sufficient for him to cultivate one quarter, or one third of his territory, he allowed the rest to remain untilled.

Fallowing has, according to this view of the subject, arisen from necessity. We know with certainty that the crops in gardens surrounding dwellings may be multiplied and continued indefinitely, by means of tilling and manuring; but the necessity for this is not felt, as long as the produce is sufficient for consumption, and when the expense attending the means of procuring an increase beyond that, would be so much clear loss.

In proportion as population has increased, lands have been cleared up, and cultivation extended and improved; so that production has always kept pace with consumption. As the wants of society permit fallowing less at this time than formerly, it has begun to disappear, especially where those wants are most pressing; and more particularly, when there is an assured prospect of an advantageous market for agricultural productions.

Fallowing was necessary as long as grains only, all of which exhaust the soil, were cultivated; during the intervals of tilling the fields, a variety of herbs grew in them, which afforded food for animals, and the roots of which, when buried in the soil by the plough, furnished a great part of the necessary manure. But at this day, when we have succeeded in establishing the cultivation of a great variety of roots and artificial grasses, the system of fallowing can be no longer supported by the shadow of a good reason.

The scarcity of dung occasioned by the limited number of cattle that could be maintained upon a farm, caused the custom of fallowing to be continued; but the ease with which fodder may be cultivated furnishes the means of supporting an increased number of animals; these in their turn supply manure and labor; and the farmer is no longer under the necessity of allowing his lands to lie fallow.

Artificial grass lands ought now to be considered as forming the basis of agriculture; these furnish fodder, the fodder supports cattle, and the cattle furnish manure, labor, and all the means necessary to a thorough system of cultivation.

The suppression of the practice of fallowing is then equally serviceable to the cultivator, who increases his productions without proportionally increasing his expenses, and to society, which derives from the same extent of soil a much greater quantity of food, and additional resources for supplying the work-shops of the manufacturer.

A great advantage has arisen from the system of a rotation of crops, which has succeeded that of fallowing. By skilfully arranging a succession of crops of grain, artificial fodder, leguminous plants, roots, &c., the earth is enriched, instead of being impoverished; the ground is cleansed from weeds, and more abundant crops are obtained at a less expense. During those years when certain fodders, such as clover, sainfoin, and trefoil, require no other care than that of harvesting them, the farmer can bestow all his attention, manures, and the labor o his cattle, upon such other portions of his farm as may need amelioration; so that, instead of having one third of his land lying as an unproductive fallow, it may be covered with herbage affording the finest food for cattle. The soil will be growing richer instead of poorer, and may be prepared for raising grain, without the addition of any manure.

What has contributed the most towards confining French agriculture to that state of mediocrity, from which neither the examples nor the writings of many enlightened theoretical farmers have been able to raise it, is the passion for cultivating too large an extent of land, with limited powers as to its arrangement. Where all the land is sown without any portion of it being properly prepared, the ground is exhausted instead of being improved by cultivation. The farmer, who takes land upon lease, has no interest in endeavoring to make it better, because the shortness of the lease does not permit him to enjoy the fruit of his labor; he is forced to reap from the land all it will produce.

Instead of including in his plans of cultivation a space of ground disproportioned to the means which are at his disposal, the intelligent farmer will at first occupy himself only with such a portion of his land as will be sufficient for his cattle, his manures, and his improvements; when this has been brought into a good state of cultivation, and a regular succession of crops established upon it, he can carry his amendments over successive portions, till, in a few years, the whole soil may be brought to yield every thing which it is capable of producing. But it is only by long leases, that a farmer can be enabled to pursue a method so wise and so secure; and long leases would be in all respects as much for the interest of the proprietor as of the farmer.

As the estate which I own is very extensive, I have not hesitated to set apart from my regular rotation of crops, about two hundred and fifty acres of land of middling quality, which had every year been manured equally with my best lands, but which had yielded but poor returns. This great extent of land is now laid down to grass, and serves as a pasture for my cows, oxen, and sheep: each year I break up one fifth part of it, and sow it with oats, rye, or barley, and the following year reëstablish it as a grass land. I am convinced that this land would never have repaid me for the expense attendant upon raising from it successive crops of grain, roots, and legumes.

CHAPTER VII.

OF THE SUCCESSION OF CROPS.

A soil may be forced, by extreme care, enormous expense, and the use of manure without measure, to produce all sorts of crops; but it is not in such sort of proceedings that the science of agriculture consists. Agriculture ought not to be considered as an object of luxury; and whenever the produce of agricultural management does not amply repay the care and expense bestowed upon it, the system followed is bad.

A good agriculturist will, in the first place, make himself acquainted with the nature of his soil, in order to know the kind of plants to which it is best adapted: this knowledge may be easily acquired by an acquaintance with the species of the plants produced upon it spontaneously, or by experiments made upon the land, or upon analogous soils in the neighbourhood.

But however well adapted the soil and climate may be to the cultivation of any particular kind of vegetable, the former soon ceases to be productive, if constantly appropriated to the culture of plants of the same or analogous species. In order that land may be cultivated successfully, various kinds of vegetables must be raised upon it in succession, and the rotation must be conducted with intelligence, that none unsuited either to the soil or climate may be introduced. It is the art of varying the crops upon the same soil, of causing different vegetables to succeed one another, and of understanding the effect of each upon the soil, that can alone establish that good order of succession which constitutes *cropping*.

A good system of cropping is, in my opinion, the best guarantee of success that the farmer can have; without this, all is vague, uncertain, and hazardous. In order to establish this good system of cropping, a degree of knowledge is necessary, which unhappily is wanting to the greater part of our practical farmers. I shall here state certain facts and principles, which may serve as guides in this important branch of agriculture.

More extensive information upon this subject may be found in the excellent works of Messrs. Yvart and Pictet.*

PRINCIPLE 1. *All plants exhaust the soil.*

Plants are supported by the earth, the juices, with which this is impregnated forming their principal aliment. Water serves as the vehicle for conveying these juices into the organs, or presenting them to the suckers of the roots by which they are absorbed ; thus the progress of vegetation tends constantly to impoverish the soil, and if the nutritive juices in it be not renewed, it will at length become perfectly barren.

A soil well furnished with manure may support several successive crops, but each one will be inferior to the preceding, till the earth is completely exhausted.

PRINCIPLE 2. *All plants do not exhaust the soil equally.*

Plants are nourished by air, water, and the juices contained in the soil ; but the different kinds of plants do not require the same kinds of nourishment in equal degrees. There are some that require to have their roots constantly in water ; others are best suited with dry soils ; and there are those again, that prosper only in the best and most richly manured land.

The grains and the greater part of the grasses push up long stalks, in which the fibrous principle predominates ; these are garnished at the base by leaves, the dry texture and small surface of which do not permit them to absorb much either of air or water ; the principal nourishment is absorbed from the ground by their roots ; their stalks furnish little or no food for animals ; so that these plants

* "Cours complet d'Agriculture," articles *Assolement* et *Succession de Culture*, par Yvart. — "Traité de Assolemens," par Ch. Pictet.

exhaust the soil, without sensibly repairing the loss, either by their stalks, which are cut to be applied to a particular use, or by their roots, which are all that remain in the ground, and which are dried and exhausted in completing the process of fructification.

Those plants, on the contrary, that are provided with large, fleshy, porous, green leaves, imbibe from the atmosphere carbonic acid and water, and receive from the earth the other substances by which they are nourished. If these are cut green, the loss of juices which the soil has sustained by their growth, is less sensibly felt, as a part of it is compensated for by their roots. Nearly all the plants that are cultivated for fodder are of this kind.

There are some plants, which, though generally raised for the sake of their seed, exhaust the soil less than the grains; these are of the numerous family of leguminous plants, and which sustain a middle rank between the two of which I have just spoken. Their perpendicular roots divide the soil, and their large leaves, and thick, loose, porous stalks readily absorb air and water. These parts preserve for a long time the juices with which they are impregnated, and yield them to the soil, if the plant be buried in it before arriving at maturity; when this is done, the field is still capable of receiving and nourishing a good crop of corn. Beans produce this effect in a remarkable degree; peas to a less extent.

Generally speaking, those plants that are cut green, or whilst in flower, exhaust the soil but little; till this period they have derived their support almost exclusively from the air, earth, and water; their stalks and roots are charged with juices, and those parts that are left in the earth after mowing, will restore to it all that had been received from it by the plant.

From the time when the seed begins to be formed, the whole system of nourishment is changed; the plant continues to receive nourishment for the perfecting of its seed, from the atmosphere and the earth, and also yields to the grain all the juices it had secreted in its own stalks and roots: by this means the stalks and roots are dried and exhausted. When the fruits have arrived at maturity the skeleton remains of the plant, if abandoned to the earth, restore to it only a small portion of what had been taken from it.

The oleaginous seeds exhaust the soil more than the farinaceous seeds; and the agriculturist cannot be at too much pains to free his grounds from weeds of that nature, which so readily impoverish them; especially from the wild mustard, sinapis arvensis, with which cultivated fields are so often covered.

PRINCIPLE 3. *Plants of different kinds do not exhaust a soil in the same manner.*

The roots of plants of the same genus or family, grow in the soil in the same manner; they penetrate to a similar depth, and extend to corresponding distances, and exhaust all that portion of the soil with which they come in contact.

Those roots which lie nearest the surface, are more divided than those that penetrate deeply. The spindle or tap roots, and all those that penetrate deeply into the earth, throw out but few radicles near the surface, and consequently the plant is supplied with nourishment from the layers of soil in contact with the lower part of the root. Of the truth of this I have often had proof, and I will mention an example. If, when a beet or turnip is transplanted, the lower portion of the spindle be cut off, it will not grow in length, but in order to obtain its supplies of nourishment from the soil, it will send out radicles from its sides, which will enable it to obtain the necessary supplies from the upper layers of the soil; and the root will become roundish instead of long.

Plants exhaust only that portion of the soil which comes in contact with their roots; and a spindle root may be able to draw an abundance of nourishment from land, the surface of which has been exhausted by short or creeping roots.

The roots of plants of the same and of analogous species always take a like direction, if situated in a soil which allows them a free developement; and thus they pass through, and are supported by, the same layers of earth. For this reason we seldom find trees prosper that take the place of others of the same species; unless a suitable period has been allowed for producing the decomposition of the roots of the first, and thus supplying the earth with fresh manure.

To prove that different kinds of plants do not exhaust the soil in the same manner, it is perhaps sufficient for me to state, that the nutrition of vegetables is not a process altogether mechanical; that plants do not absorb indiscriminately, nor in the same proportions, all the juices and salts that are presented to them; but that either vitality, or the conformation of their organs, exerts an influence over the nutritive action; that there is on the part of plants some taste, some choice regarding their food, as has been sufficiently proved by the experiments of Messrs. Davy and de Saussure. It is with plants as it is with animals, there are some elements common to all, and some peculiar to each kind: this is placed beyond doubt, by the preference given by some plants to certain salts, over others.

Principle 4. *All plants do not restore to the soil either the same quantity or the same quality of manure.*

The plants that grow upon a soil, exhaust more or less of its nutritive juices, but all return to it some remains, to repair a part of its loss. The grains and the oleaginous seeds may be placed at the head of those which exhaust a soil the most, and repair the least the injury done it. In those countries where plants are plucked up, they return nothing to the soil that has nourished them. There are some plants, to be sure, besides those mentioned above, that by forming their seed consume a great part of the manure contained in the soil; but the roots of many of these soften and divide the soil to a considerable depth; and the leaves which fall from the stalk during the progress of vegetation restore to the earth more than is returned by those before mentioned. There are others still, the roots and stalks of which remaining strong and succulent after the production of their fruits, restore to the soil a portion of the juices they had received from it; of this kind are the leguminous plants.

Many plants that are not allowed to produce seed exhaust the soil but very little; these are very valuable in forming a system of successive crops, as by introducing them into the rotation, ground may be made to yield for many years without the application of fresh manure; the varieties of trefoil, especially clover and sainfoin, are of this sort.

Principle 5. *All plants do not foul the soil equally.*

It is said that a plant fouls the soil, when it facilitates or permits the growth of weeds, which exhaust the earth, weary the plant, appropriate to themselves a part of its nourishment, and hasten its decay. All plants not provided with an extensive system of large and vigorous leaves, calculated to cover the ground, foul the soil.

The grains, from their slender stalks rising into the air, and their long, narrow leaves, easily admit into their intervals those weeds that grow upon the surface, which, being defended from heat and winds, grow by favor of the grain they injure.

Herbaceous plants, on the contrary, which cover the surface of the soil with their leaves, and raise their stalks to only a moderate height, stifle all that endeavours to grow at their roots, and the earth remains clean. It must be observed, however, that this last is not the case unless the soil be adapted to the plants, and contain a sufficient quantity of manure to support them in a state of healthy and vigorous vegetation: it is for want of these favorable circumstances that we often see these same plants languishing, and allowing the growth of less delicate herbs, which cause them to perish before their time. Vegetables sown and cultivated in furrows, as are the various roots and the greater part of the leguminous plants, allow room for a large number of weeds; but the soil can be easily kept free by a frequent use of the hoe or weeding fork; and by this means may be preserved rich enough for raising a second crop, especially if the first be not allowed to go to seed.

The seeds that are committed to the ground often contain those of weeds amongst them, and too much care cannot be taken to avoid this: it is more frequently the case, however, that these are brought by the winds, deposited by water, or sown with the manure of the farm-yard.

The carelessness of those agriculturists who allow thistles and other hurtful plants to remain in their fields, cannot be too much censured; each year these plants produce new seeds, thus exhausting the land and increasing their own numbers, till it becomes almost impossible to free the soil from them. This negligence is carried by some to such an extent, that they will reap the grain all around the thistles, and leave them standing at liberty to complete their growth and fructification. How much better it would be to cut those hurtful plants before they flower, and to add them to the manure of the farm. From the principles which I have just established, we may draw the following conclusions.

1st. That however well prepared a soil may be, it cannot nourish a long succession of crops without becoming exhausted.

2d. Each harvest impoverishes the soil to a certain extent, depending upon the degree of nourishment which it restores to the earth.

3d. The cultivation of spindle roots ought to succeed that of running and superficial roots.

4th. It is necessary to avoid returning too soon to the cultivation of the same or of analogous kinds of vegetables, in the same soil.*

5th. It is very unwise to allow two kinds of plants, which admit of the ready growth of weeds among them, to be raised in succession.

6th. Those plants that derive their principal support from the soil should not be sown, excepting when the soil is sufficiently provided with manure.

7th. When the soil exhibits symptoms of exhaustion from successive harvests, the cultivation of those plants that restore most to the soil, must be resorted to.

These principles are confirmed by experience; they form the basis of a system of agriculture rich in its products, but more rich in its economy, by the diminution of the usual quantity of labor and manure. All cultivators ought to be governed by them, but their application must be modified by the nature of soils and climates, and the particular wants of each locality.

To prescribe a series of successive and various harvests, without paying any regard to the difference of soils, would be to commit a great error, and to condemn the system of cropping in the eyes of those agriculturists, who are too little enlightened to think of introducing into their grounds the requisite changes.

Clover and sainfoin are placed amongst the vegetables

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* In addition to the reasons I have given why plants of the same or analogous kinds should not be cultivated in succession upon the same soil, there is another which I will here assign. M. Olivier, member of the French Institute, has described with much care all the insects which devour the neck of the roots of grain; these multiply infinitely, if the same or analogous kinds of plants be presented to the soil for several successive years; but perish for want of food, whenever plants not suited to be food for their larvæ, are made to succeed the grains. These insects belong to the family of Tipulæ, or to that of flies. — (Sixteenth Vol. of the *Memoirs of the Royal and Central Agricultural Society of Paris.*)

that ought to enter into the system of cropping, but these plants require a deep and not too compact soil, in order that their roots may fix themselves firmly.

Flax, hemp, and corn require a good soil, and can be admitted as a crop only upon those lands that are fertile and well prepared.

Light and dry soils cannot bear the same kind of crop as those that are compact and moist.

Each kind of soil, then, requires a particular system of crops, and each farmer ought to establish his own upon a perfect knowledge of the character and properties of the land he cultivates.

As in each locality the soil presents shades of difference, more or less marked, according to the exposure, composition, depth of the soil, &c., the proprietor ought so to vary his crops, as to give to each portion of the land the plants for which it is best adapted; and thus establish a particular rotation of crops upon the several divisions of his estate.

The wants of the neighbourhood, the facility with which the products may be disposed of, and the comparative value of the various kinds of crops, should all be taken into the calculation of the farmer, in forming his plan of proceedings.

In England and some of the northern countries, the cultivation of barley returns frequently in their successive crops, because the number of breweries afford a sure market for that grain. In Belgium, Russia, and upon the borders of the Rhine, rye is generally cultivated on account of immense distilleries of spirit: the wants of the great numbers of animals that are supplied by the malt and refuse of these works, gives every encouragement for the cultivation of that particular kind of grain.

The cultivation of woad and madder would be more advantageous in the vicinity of great manufactories, where coloring is executed, than in those countries which afford no consumption of these articles. In France, where the abundance and low price of wine will not permit us to hope for any market for beer; in France, where the greatest portion of the people live principally upon bread made from wheat, that grain is cultivated everywhere, where it can be made to grow; only the inferior soils are appropriate to the cultivation of other grains.

There is another point in regard to crops that ought to be well weighed by the farmer: though his lands may be suited to cultivation of a particular kind, his interests may not allow him to enter upon it. The more abundant any article is, the lower will be its price; he ought then to prefer those crops of which the sale is most secure. If a product cannot be consumed upon the spot, it is necessary to calculate the expense of transporting it to a place of sale in countries where it is needed.

A proprietor ought to provide largely for the wants of his animals and of the men living upon his estate, before arranging for the disposal of surplus crops: he will then calculate his various harvests in such a manner as to be always secure of receiving from the earth the means of subsistence for those employed in performing the labor.

An intelligent farmer, whose lands lie at a distance from a market, will endeavour to avoid the expenses incident to the transportation of his products; and in order to do this, he will give the preference to those harvests of fodder or of roots which may be consumed upon the place by his dependants and his animals.

There is another circumstance which must be attended to in sowing those lands which are light, or which lie upon a slope; for these it is necessary to employ such vegetables as cover the soil with their numerous leaves, and unite it in every direction by their roots, thus preserving it from being washed away by rains, and at the same time protecting it from being too much dried by the burning rays of the sun.

In order to support by example the truth of the principles which I have here laid down, I will make a statement of the series of crops that are found most advantageous in those countries where agriculture is the most flourishing. I shall commence with the provinces of ancient Flanders, because there the art of cultivating the soil to the greatest advantage had its birth.

In the departments of Lille and Douai, where the soil is of the best kind, and the art of preparing and employing manures is carried to the greatest perfection, the following series of crops are adopted.

First Series. Flax or cabbage.
Wheat.
Beans.
Oats, with trefoil.
Trefoil.
Wheat.

Second Series. Turnips.
Oats or barley, with trefoil.
Trefoil.
Wheat.

Third Series. Potatoes.
Wheat.
Roots, such as turnips or beets.
Wheat.
Buckwheat.
Beans.
Oats and trefoil.
Trefoil.
Wheat.

In this rotation of crops we find that after the soil has been manured, the crops that are most exhausting are replaced by those that are less so; and those that foul the soil, by those that cleanse it by requiring frequent weedings.

It is by similar means that nearly the whole sea coast of Belgium, consisting of sterile sand, has been rendered as fertile as the best soil; and the richest harvests have followed from a judicious system of cropping.

Upon the sands in the neighbourhood of Bruges, Ostend, Nieuport, Arvens, &c., the cultivation of the grains is made to alternate advantageously with that of beans, cabbage, potatoes, and carrots. The system of cropping practised in Norfolk, and so much praised by the English, consists in commencing the series by the cultivation of roots in a well manured soil; these are followed by oats or barley with trefoil, and afterwards by wheat.

In the bed of dry sand which forms the soil of Campine, the industrious inhabitants have with equal success vanquished all obstacles, and fertilized the soil. It is surprising to find in these plains of sand, excellent crops, which, by their judicious arrangement, are constantly ameliorating the soil. The series which is there followed is this.

Potatoes.
Oats and trefoil.
Trefoil.
Rye.
Turnips

During a tour which I made with Napoleon in Belgium, I heard him express to one of the council of a department, his surprise at the vast extent of waste land over which he had just travelled: he was answered thus; "Give us a canal to transport our manures, and to convey away our produce, and in five years this sterile country will be covered with crops." The canal was afterwards constructed, and the promise realized in less than the required time.

In the interior of France, where cattle subsist almost entirely upon fodder, and are not, as in the northern countries, fed upon the mash from breweries and distilleries, crops of the various plants used for their support should be more extensively cultivated, and should occur more frequently in the rotations.

In all the compact and slightly argillaceous soils upon my estates, if they are deep, after having had them well dressed with barn-yard manure, I commence my series of crops with beets, to which succeeds wheat, which I sow immediately after having drawn the beets, and without any intermediate tilling; the wheat I replace by artificial grasses, and these by oats. When the land is of very good quality, I follow wheat by clover, and this in its turn is succeeded by the grains, and by roots.

In light soils, which are deep and sandy but fresh, such as those upon the borders of the Loire, which are submerged once or twice every winter, I sow, first, winter vetches, which produce abundantly, and these I replace by beets.

Independently of the use which I have for beets in my sugar manufactory, I believe this plant may be cultivated as food for cattle, more advantageously than any other. The leaves of those that have completed their growth, may be used as food for animals during the months of August and September; and the roots supply a quantity of nourishment of from twenty to thirty thousand weight per acre, or more than forty thousand per hectare.

Lands of the best kind, that is to say, lands which, to a good mixture and sufficient depth, unite a favorable exposure and suitable manures, may receive into their series of crops all the plants adapted to the climate; but there are not many soils possessing all these qualities.

In the siliceous, and calcareous soils, as they are generally dry, may be alternated crops of rye, barley, and white rye, with those of sainfoin, lupines, lentils, French beans, chick peas, radishes, woad, buckwheat, potatoes, &c.

Preference should always be given to those crops which experience has declared to be best suited to the soil and climate, as well as to those of which the products are the most advantageous to the proprietor.

In compact lands, containing a portion of clay, and which from their quality are suitable for wheat, the successive crops may consist of wheat, oats, trefoil, clover, vetches, beans, turnips, radishes, cabbages, mustard, &c. A succession or rotation of crops should be established in these various soils, according to the principles which I have explained.

A succession of crops well conducted, economizes labor, manure, expense of transportation, &c.: it furnishes the means of raising and fattening a greater number of animals, and it ameliorates the soil to such a degree as entirely to change its nature; so that the most delicate plants, and those requiring the most nourishment, may be raised in a soil originally sterile and ungrateful. The arid sands of Belgium, and many of the alluvions on the borders of our great rivers, offer numerous examples of the truth of this. A good system of cropping alone can give security of a lasting prosperity in agriculture.

CHAPTER VIII.

VIEW OF THE PRODUCTS OF FRENCH AGRICULTURE.

A REGISTER of the products of French agriculture, made with great care from 1800 till 1812, gives as the mean result of these twelve years,*

1. Wheat	51,500,200	hectolitres.†
2. Rye and meslin (*méteil*) .	30,290,161	
3. Indian corn	6,302,316	
4. Buckwheat	8,509,473	
5. Barley	12,576,503	
6. Dry pulse	1,798,616	

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* For the details relative to the various products here united in a tabular form, the reader may consult my *Treatise on French Industry*. He will there find, not only the observations and the data which were deemed necessary to establish these results, but also the valuation and estimate of all these products in money.

[† The *hectolitre* is equivalent to 22.009667 gallons. — TR.]

7. Potatoes	19,800,741	hectolitres.
8. Oats	32,066,587	
9. Small grains	1,103,177	
10. Wines	35,358,890	
11. Wool, merino	790,175	kilogrammes.*
half-breed	3,901,881	
common	33,236,487	
Total	37,928,543	kilogr.
12. Cocoons of silk	5,157,609	kilogr.
13. Hemp and flax	49,677,300	
14. Oils of all kinds	130,000,000	

Independently of the principal products of French agriculture above enumerated, there are several distinct crops, which, without presenting such large results, enrich certain localities; as, for example, madder, saffron, hops, woad, fruits, green pulse, &c.

I think it proper to add to the above table, that of the animals which are more or less employed in agriculture.

1. Oxen	1,701,740
2. Bulls	214,131
3. Cows	3,909,959
4. Heifers	856,122
5. Horses or mules	1,406,671
6. Colts	464,659
7. Pure merino sheep	766,310
8. Half-breed merino sheep	3,578,748
9. Common sheep	30,845,852
10. Swine	3,900,000

CHAPTER IX.

OF THE NATURE AND USES OF THE PRODUCTS OF VEGETATION.

The elements that enter into the composition of plants, are but few in number; but the proportions in which they are combined establish so great a difference in the products of vegetation, that it seems almost incredible, that

[* The *kilogramme* is equivalent to 2.20548 lbs. avoirdupois. — Tr.]

these should be the effect of so small a number of principles, varying only in the proportions in which they are united.

The aliments of plants are water, air and manures: these substances absorbed by the leaves, the fruits, or the roots, furnish by analysis, carbonic acid, hydrogen, a little azote, and some earthy and saline principles: it is from these materials that the almost endless variety of widely differing products of plants is formed by their organs.

During the progress of vegetation these products are found to undergo successive changes; that which is first acid becomes sweet; that which is tender becomes hard, and all is owing wholly to the constant changes taking place in the proportions of the constituent principles; and one is astonished at finding that the most exact analysis of substances possessing the most opposite characteristics, detects no other difference than some hundredths more or less in the proportions of their elements.

When a plant has completed or terminated its various stages of vegetation, the dead remains, if exposed to the action of the same agents, such as air, water, and heat, suffer a succession of retrograde changes; they are gradually decomposed, and their constituent principles enter into combination with those of the bodies by which they are acted upon; thus the dead plant is entirely governed by those invariable physical and chymical laws, which in the living plant are governed and modified by the laws of vitality, the action of which regulates that of all external agents, and produces results which we can neither explain nor imitate.

Though great caution should be used when endeavouring to establish an analogy between two modes of existence differing so widely as those of animals and vegetables, it must be perceived that there is a resemblance in the manner in which both are nourished.

Animals inhale air by their lungs, or absorb it by glands scattered over their bodies; they are nourished by solid aliments received into their stomachs, or into some analogous organ: plants absorb air by their leaves and fruits, and imbibe through their roots the nutritive juices contained in the earth. In animals, the juices circulate through every part, and pass into all the various organs, in which they are elaborated, in order to form all the products which belong to this kingdom: in vegetables the juices are carried into the bark, the alburnum, the pith, the wood, the leaves and the fruit, by tubes and glands, which are arranged in hexagonal cells, and are very numerous in the parenchyma, and in the cortical layers of the bark: the juices undergo particular modifications in the various organs, and form in each one of them new compounds differing from each other.

The leaves receive the sap in vessels of the most delicate texture; in these it is elaborated, and combined with substances absorbed from the atmosphere, whilst the surplus of water, as well as the oxygen of the carbonic acid from which they have extracted the carbon, is given out by the leaves through their transpiring pores. The sap, after experiencing these changes, passes into the organs of the plant, where it is subjected to new elaborations.

The leaves are to plants what the lungs are to animals; those receiving the sap, as these do the blood, to be mingled in them with the gas absorbed from the atmosphere, and to pass thence into the great vascular system; and from both leaves and lungs the superfluous water and gases are thrown out into the air.

We likewise find a great variety of structure amongst the various species of which the two kingdoms are composed; some have a soft, loose, parenchymatous formation; others present a harder and dryer tissue; this, in vegetables, is owing to the predominance of carbon; in animals, to that of phosphate of lime; these two principles, though very different, form the basis of their separate structures. The same elements enter into the composition of all the products, whether animal or vegetable; the difference between them arising solely from the different proportions of the constituent principles.

An analysis of the principal products of vegetation has been made with great care by Messrs. Gay-Lussac and Thénard. The results of these researches enable us already to draw some conclusions in regard to the character of any one of the products, according as this or that principle may predominate in its composition; or according to the nature of the elements combining to form it. Thus we know,

1. That a vegetable substance is acid when it contains no azote, and when the quantity of oxygen in proportion to that of hydrogen, is greater than is necessary for the formation of water

2. That when the proportion of hydrogen to that of oxygen is greater than is necessary for the formation of water, the substance is oily, resinous, alcoholic, or ethereal.

3. That when the quantity of oxygen and hydrogen contained in a substance is the same as in water, the substance is analogous to sugar, gum, fibre, &c.

I shall in this work speak only of such products of vegetables as are most common, or of the most extensive use, either for domestic purposes, or in the arts; and I shall endeavour as much as possible to follow the order prescribed by the analogy of their constituent principles.

ARTICLE I.

Gum and Mucilage.

Mucilage appears to be in the greater part of vegetables the effect of the first change wrought upon the sap by the laws of vitality; and the gums, which differ so little from it, are generally formed upon trees by the extravasation of the sap, during the period of most vigorous vegetation. This first product of vegetation appears, however, to be permanent through all its stages: the leaves of the marsh mallows, the seeds of flax, lichens, and the bulbs of hyacinths furnish it at all times; so that it appears to be a constant and inherent product of their composition.

Gum exists in a liquid form in the cells of plants; it hardens by exposure to the air, loses a portion of its transparency, experiences a greater or less change of color, and becomes slightly brittle. Mucilage preserves its consistency a longer time, though it has less affinity for water

Gum and mucilage are soluble in water, from which they may be precipitated by alcohol, and by sulphuric acid: they burn with difficulty, and during ignition give out but little flame, and produce a great deal of smoke; their residuum consists of bubbles of carbon.

The gums that are most used in the arts, are gum Arabic, gum Senegal, and the reddish gum of the country, which forms in tears upon the branches and trunks of plum, cherry, apricot, and many other trees.

Gum and mucilage may be employed as food; mucilage is sometimes prescribed in medicine as a mild, soothing, and easily digested article of nourishment.

The use of gum in the arts is very extensive; it is used in preparing cloths and felt for receiving a gloss; writing-paper is covered with a thin coating of it to prevent the ink from spreading. Gum is used as a receiver of the colors, which are applied by impression to cloths of all kinds: the use of it in stamping cotton and linen goods is now superseded in England by that of mucilage extracted from lichens.

The specific gravity of the gums is from 1300 to 1490, water being 1000. Messrs. Gay-Lussac and Thénard found gum Arabic to contain

Carbon	42.23
Oxygen	50.84
Hydrogen	6.93

Oxygen and hydrogen are found in it in the proportions necessary for forming water.

ARTICLE II.

Starch or Fecula.

STARCH is a white, finely divided, pulverulent substance, insoluble in cold water, and forming a glue in boiling water. When this substance is obtained from any other plant than one of the grains, as from potatoes, corn-flag, bryony, horse-chestnut, male orchis, dog-bane, burdock, iris, hen-bane, patience, ranunculus, &c., it is known by the name of fecula.

In many parts of America the principal food of the inhabitants is procured from the fecula of the manioc. The preparation of sago from the pith of old palm trees, and of salep from the bulbs of all the varieties of orchis, shows the important purposes which may be answered by the fecula of various plants, in the arts, in medicine, and as nourishment for the human species and for animals. The fecula contained in all the plants I have just named is wholesome, and very nourishing, and may be used as food in various forms; but it is necessary to keep in mind, that in most of these vegetables it is combined with other substances either actually poisonous, or possessing a sharp, bitter, acrid, or otherwise disagreeable taste: it is therefore of the greatest consequence that the fecula should be prepared from them with the utmost attention to freeing it from every other portion of the plant. Fortunately the nature of the substances which are united with the fecula is so different from that of the fecula itself, and the characteristics of each are so distinct, and so well marked, that they can be separated from each other by a process equally easy and sure. The great solubility in water of all the injurious principles, and their extreme levity when compared with the weight of the fecula, causes them, when exposed to repeated washings, to rise to the top of the vessel in which the operation is performed, whilst the fecula, freed from any mixture, remains at the bottom.

Two processes are employed for extracting fecula; both must be commenced by reducing to a state of fine division the substance containing it. The fecula is afterwards obtained either by means of cold water alone, or by fermentation. The first of these methods is the most simple and expeditious, but by it all the fecula is not obtained; the second, therefore, though longer and more expensive is preferred for extracting starch from the grains.

When starch is to be extracted by cold water, the substance must either be reduced to the state of flour, or be broken so that the pulp can be acted upon by the water.

In the first case, the flour of wheat is kneaded with water, till it takes the consistency of a stiff paste; this is placed on a cloth stretched tightly over a tub, and cold water thrown upon it; the kneading with the hand is continued till the water runs off clear; the fecula is carried off by the water and deposited at the bottom of the tub; the water retains in solution the sugar and the extractive matter of the farina, whilst the insoluble gluten alone remains upon the filter; the deposit is washed to free it from any foreign substance, and then dried. When it is not wished that the substance containing the fecula should be reduced to flour, it may be broken in a mortar, or under a mill-stone, or it may be grated; the pulp is then to be placed upon a very fine horse-hair sieve, and water thrown upon it till it runs off clear; care being taken to stir the pulp constantly with the hand and to squeeze it hard.

When the substance from which the fecula is to be extracted is fleshy, and of a loose, spongy texture, it can be reduced to a pulp by means of a press; the juice thus expressed deposits the fecula, which must be very carefully washed, in order that the noxious principles contained in it may be perfectly separated. The whiteness and excellence of the fecula depends upon its being thoroughly washed.

Fermentation is the means most commonly employed for extracting starch from grain; but this operation will produce only alcohol, if care be not taken in mixing the acid with the grain to prevent the spirituous fermentation. This acid is made by mixing with a bucket of hot water two pounds of baker's yeast, to which is added, two days after, several buckets of hot water; in forty-eight hours from that time the acid will be sufficiently developed.

This acid, which is called by the starch manufacturers *sure water*, contains nothing but vinegar, and I therefore presume, that the acetic acid may be used with the same success.

In order to extract the starch by fermentation, a bucket of this *sure water* is thrown into a hogshead having one end taken out. The hogshead is then filled half full of common water, into which flour is stirred till it is full; the whole is then left to macerate during ten days in summer, and fourteen in winter. The sufficiently advanced state of the maceration may be known by a deposit being formed, and the liquor swimming above it remaining clear, whilst the surface is covered with foam or *fat water*. The water and foam is drawn off, and the deposit is thrown into a sack of hair-cloth, which is placed in a tub, and water thrown over it till it runs off without any cloudiness. The substance remaining in the bag, which is only the coarsest part, serves as food for cattle. At the end of two or three days, the water floating above the deposit formed in the tub is drawn off, and a part of it preserved to serve as *sure water*, for succeeding operations.

In order to have good starch, the deposit must be washed in a great deal of water and well mixed; two or three days after, the water for the remaining washings may be thrown on.

The deposit which is formed presents three layers differing widely in their quality; the first is principally composed of fragments, and is taken off as food for cattle, or to fatten hogs with. The second layer is generally formed of the mealy part of the vegetable mixed with some other substances: the product of this layer is known under the name of common starch.

The third layer contains the purest and heaviest starch; but in order to give it all the qualities it ought to possess, it must be washed with water, and the water afterwards separated from it by filtration through a sieve of silk, so as to free it from all impurities. With these precautions starch may be obtained fitted for any use.

As soon as the starch has been well washed, it is put into baskets lined with linen, to be well drained. It is afterwards divided into loaves, and the drying finished by exposing it in the open air upon laths. Before packing for sale, the surface of the loaves, which is slightly colored, is scraped, and the drying of them is completed in the sun or in a stove.

The use of starch and of fecula is very extensive; starch mixed with boiling water, takes the consistency of jelly, and forms size; when tinged with blue, it is used for giving a gloss and stiffness to linen; when reduced to a fine powder, it is used for dressing the hair. Fecula forms the basis of the greater part of our food, and is in itself an excellent article of nourishment.

Starch acted upon by sulphuric acid is converted into sugar, and in this state may be made to undergo the vinous fermentation. A few years since extensive establishments were formed in France, for supplying numerous distilleries with the fecula of the potato, which had been treated in this manner.

Starch thrown upon red-hot iron, burns, leaving scarcely any residuum.

Messrs. Gay-Lussac and Thénard have found that 100 parts of starch contain

Carbon	43.55
Oxygen	49.68
Hydrogen	6.77

So that in starch, as in gum and mucilage, oxygen and hydrogen are combined in the same proportions as in water; and those substances resemble starch in their characteristics, and in their uses.

ARTICLE III.

Sugar.

Sugar is a substance of a sweet and agreeable taste which is extracted from certain vegetables: it is light colored, and when dissolved in water to which a little yeast has been added, is capable of undergoing the vinous fermentation. All those substances that experience the same fermentation by the same means, contain more or less sugar. The same characteristic may be bestowed by art upon many other products of vegetation, causing them to vary, by chymical processes, the proportions of their constituents, till they approach those of sugar; it is in this way that starch and vegetable fibre may be made to undergo the vinous fermentation. All those substances that possess the property of forming the vinous fermentation, may be called by the general name of sugar. There are three kinds of sugar, the characteristics of which are very distinct; the first and most important is that which crystallizes, and to which the generic name of *sugar* is given; this is furnished by the sugar cane, the beet, carrot, turnip, chestnut, maple, &c.

The sugars procured from these different plants, are, strictly speaking, of the same nature, and do not, when brought by the process of refining to the same degree of purity, differ in any way from each other: their taste, manner of crystallization, color, and weight are then precisely the same, and no person, however much in the habit of judging of these products, or of consuming them, can distinguish one from the other.

The second kind of sugar, is that which is extracted from the must of grapes; this always appears in the form of a white powder, in which no trace of crystallization can be found; it possesses the properties of the first kind of sugar, and provided a double portion of it be used, answers the same purposes. During the time when American sugar was scarce, and consequently excessively dear in France, an enormous quantity of grape sugar was manufactured and sold at a low price.

The third kind of sugar, is that which is contained in nearly all fruits; this not only refuses to crystallize, but cannot be made to assume solid form. The juices of these fruits may be reduced to a sirup supplying for many purposes the place of sugar, and of great use as an article of food. By concentrating these nutritive substances, the advantage of reducing them to a small bulk is added to that of preserving them from decomposition: the same effects are produced by concentrating them to a jelly or an extract. Those sweet juices, that are not convertible into sirups, will, by being fermented, form a vinous liquor, equally useful, healthful, and agreeable, to a great portion of the people.

Those substances, which are, by the aid of chymistry, convertible into sugar, furnish only the second kind of it; this is very suitable for being made by fermentation to produce alcohol.

The specific gravity of sugar is, according to Fahrenheit, 1.6; it dissolves in its own weight of water, at the temperature of 50°. Sugar contains 42.47 per cent. of carbon; hydrogen and oxygen are found in it as in the gums, in the same proportions as in water.

ARTICLE IV.

Wax.

Though wax can be extracted in considerable quantities only from the berries of the *myrica cerifera*, yet it is contained in nearly all plants; it exists in greater or less quantities in the leaves of most trees. Wax is also formed by the decomposition of several roots; for if, when the first operations are performed for extracting sugar from the juice of beets, they be not well conducted, from the moment the boiling of the concentrated sirup, in order to form the sugar, is commenced, there collects upon the surface a thick, whitish, glutinous substance, which, when removed with the skimmer and dried, exhibits all the characteristics of wax; it is insoluble either in water or alcohol; it burns like wax, and has the same consistency; nor does it in any other respect differ from it. It is this substance that adheres to the sides of the boilers when the sirups have become thickened by boiling, beyond 35° of the aërometer of Baumé. The burning of the liquor, which prevents the ebullition from being carried to a sufficient extent to produce a good crystallization of the sugar, is caused by this substance. There cannot be too much care taken in the first operations to prevent this deterioration of the sirup, as this alone has occasioned the failure of most of the establishments, which were formed in France in 1810, for manufacturing sugar from beets.

Nearly all the wax which is used in the arts, and for domestic purposes, is produced by bees, the cells of their hives being formed by it. This wax is found in scales or plates under the abdomen of the insect, and appears to be a transudation, which becomes thickened, and which the bee detaches by rubbing, to form his cells.

Wax is bleached by pouring it when melted upon a cylinder partly immersed in water, and to which a rapid rotatory motion is given. The wax, as it flows over the moistened surface of the cylinder, congeals in very thin layers, which are afterwards exposed upon cloths in the sun for some time, that they may acquire a clear whiteness.

It does not appear, that in the elaboration of wax, the bee bestows upon it any animal character whatever; the wax which is furnished by bees is precisely of the same nature as that procured directly from some vegetables. Wasps build cells, which they use for the same purposes as the bees do theirs; but the materials of which they are constructed is ligneous, and consists of minute portions of the fibrous part of vegetables cemented by an animal gluten. According to the analysis of Messrs. Gay-Lussac and Thénard, 100 parts of wax are composed of

Carbon	81.784
Oxygen	5.544
Hydrogen	12.672

The property possessed by wax, of burning without producing either odor or smoke, has caused it to be generally used for lighting the apartments of the wealthy: tallow and the common oils have always been used by the poor, and they are so even at this day, when science and chymistry have united to perfect the mode of lighting by oil.

ARTICLE V.

*Oils.**

The oils are fat, unctuous bodies, of various degrees of fluidity, insoluble in water, forming soap with the alkalies, and burning and evaporating at different temperatures. It is the last characteristic, particularly, which establishes that difference amongst them by which they are divided into fixed and volatile oils. The fixed oils are contained in seeds and fruits, from which they are extracted by pressure. The first portion which is expressed is the purest, and is known by the name of virgin oil; that which follows is rendered more or less impure by the mixture of other principles contained in the fruit submitted to compression. It is particularly by the mucilage, which is found in a greater or less quantity in all vegetables, that the purity of oil is affected.

After all the oil, which can be extracted by pressure, has been drawn off, it is customary to moisten the mash with boiling water, and to subject it to another and more powerful pressure; but the oil thus obtained carries with

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* I make use of the generic term *oil*, by which two substances, differing widely from each other, have been for a long time known; but I ought to observe, that the properties which are common to them, are not sufficient to authorize their being included under one name, and that in all their relations they present so great a difference as to entitle them to be considered as two kinds of products, and to be designated by specific names.

1. The fixed oils are insoluble in alcohol; the volatile oils are soluble.

2. The fixed oils have generally neither odor nor flavor; the volatile oils are pungent, caustic, and very odoriferous.

3. The property of burning, common to the two oils, belongs likewise to all vegetable substances properly so called.

4. The fixed oils are obtained only from seeds and fruits; many volatile oils are extracted from all parts of plants.

5. The fixed oils are for the most part employed as food; the volatile oils are useful only in the arts.

6. The fixed oils evaporate only at a high degree of temperature; the volatile oils are dissipated entirely at the temperature of the atmosphere.

7. The characteristic of forming soap does not belong exclusively to the oils; it is possessed by many other substances, animal and vegetable.

Thus what are called volatile oils are only liquid or concrete aromas, and it is in the class of aromas that they ought to be ranked.

it a large portion of mucilage, and is usually employed only in some of the trades. In some countries it is customary to collect the fruits into heaps, and to subject them to a degree of fermentation before pressure; by this means the extraction of the oil is rendered easier, and the quantity of it is increased, but the quality of it is much injured. Similar results are obtained by breaking the fruit previous to expressing the oil.

It would be hardly right to condemn these last methods as erroneous, because in the numerous soap-works, dye-houses, cloth manufactories, &c., this quality of oil is preferred to that which is purer. The learned will do well to condemn the processes now employed for procuring the fine oils, and to prescribe others by which we may obtain them purer and of a better taste; but the grand consumption of the oils is in the manufactories, and there the fine oils would very imperfectly replace those of a coarser kind; thus, by perfecting the produce, the usefulness of it would be lessened. When oil is to be extracted for domestic purposes, it is without doubt desirable that it be obtained as pure as possible; but that which is destined to be employed in the trades, and in manufactures, as in that of soap for instance, is the better for being combined with a portion of mucilage. The great art of manufacturing consists in appropriating the products to the wants and tastes of consumers.

When mucilage is so abundant in an oily seed, that it yields upon expression only a pasty combination of mucilage and oil, the seed is dried by fire: when the mucilage is thus deprived of fluidity, the oil flows off pure. In this manner the seeds of flax, of poppies, of hen-bane, &c. are prepared for expression.

Nearly all oils are colored, and contain some of the principles of the fruits from which they are procured; these are in some of their effects injurious to the oil, and great pains has been taken to find some means of freeing it from them. Oil is clarified to a certain degree merely by standing in a cool place in open earthen vessels; it forms a deposit and is thus rendered purer, clearer, and better. If oil is exposed to the sun it gradually loses its color.

In order to clarify the oil of mustard, one per cent. of sulphuric acid is put into a large earthen pan, into which the oil is thrown and carefully stirred: the oil becomes green, and upon being allowed to remain at rest, forms upon the sides and bottom of the pan a blackish deposit, which is principally composed of carbon: the process must be repeated after a few days, if the oil have not acquired the wished for clearness. Before using the oil, it is necessary that it should be allowed to remain for some time undisturbed. In this operation the mucilage appears to be precipitated and consumed by the acid. Most fixed oils contain some mucilage, and most of them become rancid.

Most fixed oils have but in a very slight degree the property of drying; but some of them acquire it by being combined with some metallic oxide, and this greatly increases the use of them, as they can in this way be employed as varnishes for covering bodies which it is necessary to preserve from air and water; or as the recipients of colors to be used in painting upon cloth, wood, or metal. The best drying oils are those of flaxseed, nuts, and poppies. Linseed oil will dissolve at boiling temperature $\frac{1}{4}$ of its weight of that oxide of lead known in commerce by the name of litharge. It becomes brown in proportion as the oxide is dissolved: when saturated with the oxide it thickens by cooling, and it is necessary to render it liquid by heat at the time of using it. Linseed oil, saturated with the oxide and applied with a brush to any substance, hardens readily and forms a coating impervious by water, and much resembling gum elastic; linen or silk prepared with it is flexible without being adhesive.

A cement of this oil prepared with the oxide, and mixed with the refuse or broken fragments of porcelain or of well baked potter's ware, is used with great success in uniting the tiles upon roofs, and in cisterns, and reservoirs. To form this cement the pulverized fragments are thoroughly incorporated with the heated oil, and applied by the trowel whilst in that state.

When linseed oil is to be used in painting, $\frac{1}{20}$ or at the most $\frac{1}{10}$ part of litharge is sufficient to render it drying.

In consequence of the numerous purposes to which the fixed oils are applied, the consumption of them is immense: they form the basis of the soaps, both soft and hard, according as they are combined with potash or soda: they are used to fix in the most durable manner upon cotton the colors obtained from madder: they are employed to facilitate the operations in all establishments for carding and spinning wool. It is by the use of oil that the play of all machinery is rendered more regular and easy, and that friction is moderated; and by it metals are preserved from rusting.

The most important use to which oil has been applied is that of lighting buildings; but as it gives out, in burning, more or less smoke, and a light inferior in brilliancy to that of wax, the latter was preferred until the invention of Argand's lamps: in these a current of air passes rapidly through a circular wick surmounted by a cylindrical glass, and thus the smoke is consumed and the light rendered more clear and brilliant.

The products of the combustion of the fixed oils are water and carbonic acid; this declares their constituent principles to be carbon, oxygen, and hydrogen. Messrs. Gay-Lussac and Thénard have found them in the following proportions.

Carbon	77.213
Oxygen	9.427
Hydrogen	15.360

The volatile or essential oils are more easily volatilized than the fixed oils; they are inflammable at a lower temperature, are soluble in alcohol, exhale a powerful odor by which they are distinguishable from each other, and have a lively, acrid, and burning taste.

The volatile oils do not belong exclusively to any one part of plants: in some, as in the Bohemian Angelica, the oil is distributed throughout the whole plant: sometimes, as in balm, mint, and wormwood, it is found in the leaves and stalks: the elecampane, Florence iris, and bennet contain it in their roots; thyme and rosemary in their leaves and flower buds; lavender and the rose in their calyces; camomile, lemon, and orange plants, in their flowers; the petals, and the rind of the fruit of the two last abound in oil; that of indigo and fennel is contained in vessels forming the raised lines which may be perceived on the bark.

Volatile oils vary in color, consistency, and weight: there are some, as that of sassafras, and the clove, for instance, which are heavier than water; and there are some, as those of the rose and parsley, that remain in a concrete state at the usual temperature of the air, &c.

The volatile oils are extracted either by distillation or expression. When the oil is contained in vesicles upon the surface of the rind, as is that of the lemon and bergamot, the cells may be broken and the oil caused to flow out by merely rubbing the rinds together; or, the rinds may be taken off by grating, and the oil separated from the pulp by a light pressure, or by allowing the whole to remain undisturbed for a few days, when the pulp will settle at the bottom, and the oil remain floating above it.

When these rinds are scraped with a bit of sugar, the oil combines with it, forming an *oleo-saccharum*, useful in giving a pleasant flavor to liquors.

With the exception of the oils of which I have just spoken, all the volatile oils are extracted by distillation: in this process the plant is put into the boiler of the alembic, and covered with water; when the water boils the oil rises with the steam, and is condensed with that in the worm of the still, whence they flow together into the receiver: the oil which swims upon the top is separated from the water, and this water, which has a milky appearance, is again employed from preference in new distillations.

It is customary to make use of a narrow, straight-necked vessel as a receiver: the oil collects in the upper part of this, whilst the water passes off through a siphon in the side, about four inches below the neck.

In the south of Europe, where great quantities of the volatile oils are prepared, the distillers place their portable apparatus in the open air, in those places which offer a plentiful harvest of aromatic plants; when these are exhausted they remove elsewhere.

The aromatic oils are employed particularly as perfumes, and for this purpose are often combined with other substances. They are likewise used in the manufacture of varnishes, from the readiness with which they dissolve colors, and from their quick evaporation after being applied.

ARTICLE VI.

Resin.

The occurrence of resin is very common throughout the whole vegetable kingdom, but it is from those trees which are most numerous, as pines, cedars, &c. that it is principally extracted, and the term *resinous* is applied to them from the very great proportion of resin contained in their sap.

The mode of collecting resin is by cutting notches through the bark of the trunks of resinous trees near the base, at that season when the sap, softened by the returning warmth of spring, begins to rise in the vessels. As resin abounds principally in the alburnum, the notches must be of sufficient depth to pass through that; the incisions must be enlarged or renewed, once in fifteen days. The flow of the resin ceases as the return of frost causes the vessels of the trees to contract. A healthy and well-grown tree will furnish from twelve to fifteen lbs. of resin per annum.

A different process is made use of in extracting resin from dead trees; the bark and young branches of these are taken off, and the remainder reduced to small pieces which are piled up in a heap and covered over, excepting a small opening which is left at the top: the heat of the fire which is kindled at the upper part is sufficient to melt the resin which flows down to the bottom, and is carried off by channels, into vessels prepared to receive it.

This resin is black, and contains a great quantity of pyroligneous acid and volatile oil: it is known in commerce under the name of *tar;** the quality of it varies according to the care with which it is extracted: if the heat be too great, the volatile oil is thrown off, and the resin rendered dry and brittle: it cracks when used, and renders the substances to which it is applied less ductile and pliable.

The tar of southern climates has both faults; and it was formerly necessary that the marine arsenals should be supplied with that made in the north of Europe; but now that tar is manufactured in furnaces, according to the process of M. Darracq, in such a manner as to condense all the volatile oil, and thereby render the tar more fat, unctuous, and suitable for all purposes, it is employed for naval purposes, equally with the best tar of the north.

The resins are insoluble in water, but very soluble in alcohol: they liquefy at a low temperature, and burn easi-

* A description of the processes employed for extracting resins and forming all the resinous preparations known in commerce, may be found in my *Chimie appliquée aux Arts*. Vol. II. page 425–445.

ly, giving out much smoke during combustion. Amongst our mountains the peasants have no other method of lighting their dark dwellings, than by burning the wood of resinous trees.

The solubility of resin in alcohol occasions it to be used as a basis in the spirit-of-wine varnishes: the dissolvent evaporates as soon as the varnish is applied, and leaves a coating of resin, which preserves the body from the action of air or water, and at the same time gives to it a brilliancy, smoothness, and a beautiful color which may be varied at pleasure.

The smoke of resin condensed and collected in chambers hung with linen or paper, forms the lamp-black which is commonly employed in painting, stamping, printing, and the composition of varnish. According to the experiments of Messrs. Gay-Lussac and Thénard, 100 parts of common resin contain

Carbon	75.944
Oxygen	13.337
Hydrogen	10.719

ARTICLE VII.

Vegetable Fibre.

Vegetable fibre is the frame-work of all the solid parts of plants: it may be separated from vegetable substances by the repeated action of water and alcohol, aided by heat; by maceration for a length of time; or by distillation. By the first method the juices which are lodged in the intervals of the fibres are dissolved; by the second, these juices are decomposed by fermentation; by the third, which is the least perfect, those principles which can be volatilized by heat are driven off, but their carbon remains united to that of the fibre, which is itself decomposed, though preserving its form.

Fibre separated from all other vegetable substances by either of the two first-mentioned processes, is possessed of a great degree of flexibility, is insoluble in water or alcohol, and burns with a yellow flame.

Art has succeeded in extracting the vegetable fibre from a great variety of plants, by separating from it all those substances which would serve to hasten its putrefaction, or to diminish its flexibility: thus when the stalks of flax, hemp, broom, nettles, or the leaves of the aloe, are macerated in water, all the juices are extracted by dissolution and fermentation, and there remains only the flexible fibre, from which fabrics of linen, thread, and cordage, so extensively used, are manufactured.

The opinion which some have entertained that those stalks, which had been bruised by machinery, did not require to be softened by the action of water, appears to be erroneous: a portion of the juices may, it is true, be separated by mechanical force, but there remain some portions which adhere so closely to the fibre, that they can only be separated by maceration in water; should these be allowed to remain, they would render the fibres unfit for many purposes, and would likewise be injurious to their strength.

The size of the fibre is not the same in all the plants I have just mentioned; that of flax is finer, and more delicate than the others; from this the finest linens, cambrics, and lawns are made. The fibre of hemp is next in quality to that of flax, and is in general use: some coarse fabrics are made from the annual shoots of the broom; and the fibre of the leaves of the aloe is manufactured into cordage.

The fabrics manufactured from vegetable fibre, continue to grow soft and pliable by use, till the threads lose their consistency and tenacity; when reduced to this state, they are by the action of machinery torn into fragments, and the cohesion between the particles destroyed by means of putrefying liquids, and thus a fluid paste is formed, of which all the particles, having no union amongst themselves, swim separately in the water. These particles may, however, upon being taken from the water which divides and separates them, be made to adhere strongly to each other by a series of operations the execution of which constitutes the art of making paper. After having reduced the fibre to a pulpy liquid, the next step is to throw the liquid upon a sieve which allows the water to pass through, whilst a thin layer of the paste remains adhering to the net-work of the sieve: this takes some consistency by being separated from the water which held it in solution, and its firmness is further increased by drying: each layer forms a leaf, which only requires pressing and sizing, to be ready for use.

Though in the manufacture of paper, only fragments which have been thoroughly rotted are made use of, yet there will be found in the products the same kind of inequality as to fineness, as in the manufacture of cloths: the finest paper is made from linen rags, the coarsest from the remnants of ropes.

Charcoal consists almost entirely of the constituent principles of vegetable fibre, from which the other elements have been separated by the action of heat; and as charcoal forms the basis of vegetable fibre, I cannot well avoid speaking of it in connexion with this subject; and as it is an article of such general use, it ought surely to find a place in a work of this kind.

The vegetables of which the combustion is the most intense and lasting, are those which in their texture are closest and driest: such give out less flame in burning than others, but the heat is greater, and the superior quality of the coals produced from them causes them to be preferred for domestic heat, and for many of the operations of the arts.

In some manufactures where it is necessary to apply heat to bodies which collectively form a large mass, as in the manufactories for porcelain and potter's ware, in lime-kilns, &c., wood split fine and well dried is preferred, as it gives out much flame, and leaves but a small residuum of charcoal.

Those plants in which the longitudinal fibres are disposed in closely compacted bundles, possess all the qualities necessary for combustion; but the process is much less perfect in those which have not acquired this density, and are still full of nutritive juices, than in those which have become by age hardened into wood.

Soil, exposure, climate, and season modify in a remarkable manner the fibre of vegetables of the same kind.

Vegetables raised in a dry and arid soil have a much harder and more compact texture, than those of the same kind raised in a moist and rich soil: they have more perfume, contain a greater quantity of volatile oil, are decomposed with more difficulty, and during combustion give out a much more intense heat. Every one knows that thickets having a southern exposure, yield better fuel than those which lie towards the north; the wood is more solid, and after having been cut, it will resist for a longer time the action of air and water. This fact was observed by Pliny, in regard to the woods of the Apennines.

The plants of southern climates, when transported to the north, lose their perfume; and the insipid vegetables of Greenland acquire taste and smell when transplanted to the gardens of the south of Europe.

In the spring of the year, trees are full of juices, but they yield at that time principally mucilage; in autumn they afford oil, starch, sugar, &c. Professor Plot remarks, that in the year 1692, trees cut in the sap were devoured by worms, and that the wood warped in drying and acquired but little hardness. Julius Cæsar was convinced of this truth when he caused his vessels to be built of wood cut in the spring. And Vitruvius advised that trees should be cut down only at the close of winter, "when the power of the cold shall have compressed and consolidated the wood."

Vegetable fibre burns in the open air with a yellow flame, and disengages water and carbonic acid; distilled in close vessels it leaves a residuum of carbon: it is by this process, that the charcoal used for most purposes is procured.

The most common method of procuring charcoal consists in cutting the branches and young trunks of trees into billets of about three feet in length, and two inches in diameter; a portion of the prepared wood is laid upon the ground in parallel lines, and the remainder is piled upon it in a hemispherical form, to the height of six or eight feet; the surface is then covered over with earth or sods of grass, and the pile set on fire by means of a flue in the centre. In a short time the whole mass is heated through, and water, carbonic acid, and volatile oil are thrown out with the smoke; this will cease to appear when the wood is reduced to a black, sonorous body, and the pile may then be opened.

This process is very faulty, as in it a great part of the wood intended to be carbonized is burned up, and because great skill is requisite for carbonizing the mass uniformly.

Wood reduced to charcoal yields from $\frac{20}{100}$ to $\frac{30}{100}$ of its weight, according to the nature of the wood, and the care with which the operation has been performed.

Different kinds of wood yield coal of very different quality: the best coal is heavy and sonorous, and is produced from wood of very compact fibre. The heat it affords is quick and strong, and its combustion, though vigorous, lasts a long time. The charcoal of the green oak of the south burns at least twice as long as that of the white oak of the north, and the effects produced by the heat it affords are great in the same proportion.

The light, porous white woods afford a brittle, spongy coal of less weight, and which may be easily reduced to powder : this coal consumes quickly in our fire-places, but is useful for some purposes, particularly in the manufacture of gun-powder, for which use it is prepared by the following process : a ditch of five or six feet square, and of about four in depth, is dug in a dry soil; the ditch is heated by means of a fire made of split wood, the shoots and leaves are stripped from the young branches of elders, poplars, hazles, and willows, of which the coal is to be made, and as soon as the ditch is sufficiently heated the branches are thrown gradually in; when carbonization is at its height, the pit is covered over with wet woollen cloths. This charcoal is more light and inflammable than that of the denser woods, and is susceptible of being more easily and completely pulverized. M. Proust, who has made numerous experiments to ascertain the kind of plants which furnish the best coal for powder, found that procured from the stalks of hemp to be preferable to any other.

The most perfect process of carbonization is performed by means of a close apparatus : for this purpose a stone or brick building is constructed, of from eighteen to twenty-five feet square ; this is vaulted over, and the inside of it lined with a brick wall ; through the extent of it cast-iron cylinders are laid in such a manner, that one of the two ends shall have an external communication, whilst the other carries the smoke into one of the chimneys. As soon as the building is filled with the wood for carbonization, the cylinders may be heated. The vapor which is distilled from the wood is received into sheet-iron pipes, placed in the top, which convey it into tubs where it is condensed.

The form and dimensions of these buildings for making charcoal by means of a close apparatus, are greatly varied, but of all which I happened to see, the one I have here described appears to me the most perfect. There are many advantages arising from the use of this method, which more than repay the necessary expense of the apparatus. In the first place, a much greater quantity of charcoal is obtained, than by the ordinary process; in the second place, well made and clean charcoal is always procured; and in the third place, there is obtained a great quantity of pyroligneous acid, which may be sold for $ 1.80 or $ 2.16 per French hogshead, and which, when purified and rendered clear, may supply the place of vinegar for many purposes.

In addition to its very extensive usefulness in our workshops and for domestic fires, charcoal possesses the property of destroying disagreeable smells, and of preventing or retarding putrefaction; it is likewise useful in clarifying water, which, by being filtrated through it, loses the bad odor, which it in some instances possesses. When the inside of a cask is charred according to the plan of M. Berthollet, water may remain in it a long time unaltered, and without acquiring any bad taste. I do not doubt that the same good effect would be produced upon wine, which often acquires from the cask so disagreeable a taste as not to be drinkable.

An analysis of oak wood, and one of beech also, gave to Messrs. Gay-Lussac and Thénard the following results.

100 parts of oak wood,	
Carbon	52.53
Oxygen	41.78
Hydrogen	5.69
100 parts of beech wood,	
Carbon	51.45
Oxygen	42.73
Hydrogen	5.82

ARTICLE VIII.

Gluten and Albumen.

Gluten and albumen are substances, which, although found in the vegetable kingdom, have all the properties of animal matter; they yield an abundance of ammonia by distillation or putrefaction.

Gluten and albumen, although possessing some common properties, cannot be considered as the same, as there is an essential difference between them.

Albumen is an insipid fluid soluble in cold water, from which it may be precipitated by alcohol, the acids, or tannin; but the most distinguishing characteristic which it possesses, is that of coagulating at a degree of heat indicated by from 45° to 50° of the centigrade thermometer, (equal to from 113° to 122° Fahr.)

Proust, Clark, Fourcroy, and Vauquelin have each proved the existence of albumen in the juices and fruits of most plants.

The white of eggs consists of nothing but pure albumen: nearly all the different parts of animals contain different portions of it; it is, however, most abundant in the blood.

Besides the property which albumen possesses of serving as food, it is employed for many purposes in the arts, particularly for clarifying fluids; when used for this, it is diluted with water, and then mixed with the liquid which is to be clarified; the whole is then heated to 65° or 70° Fahr., and stirred carefully so as to distribute the albumen equally amongst all its particles; by increasing the heat the albumen is made to coagulate, when it rises to the top of the vessel, carrying with it all the particles which render the liquid turbid or cloudy; the thick foam which this produces when cooled, may be taken off with a skimmer, and the liquid be afterwards filtrated to remove any remaining particles from it.

The juice of the fruit of the Hibiscus Esculentus, (eatable hibiscus, *Okra*,) contains so great a quantity of albumen, that in St. Domingo it is employed in clarifying liquors; in Martinique and in Guadaloupe they make use of the bark of the slippery elm for the same purpose.

As albumen dries easily, and covers all bodies to which it is applied in thin layers, with a smooth and shining varnish, it is used for giving lustre to paintings, wainscots, &c.

The albumen of eggs mixed with quicklime finely powdered and spread upon strips of linen, makes an excellent lute, to be applied over the joints of vessels for distilling, where it is necessary to avoid any loss of gas or vapor. The white of eggs is preferred for such purposes, because the albumen of it is more free from mixture than that of any other substance. An analysis of the white of eggs afforded to Messrs. Gay-Lussac and Thénard the following results: 100 parts of the white of an egg contained

Carbon	52.883
Oxygen	23.872
Hydrogen	7.540
Azote	15.705

Gluten appears to exist more extensively than albumen in the vegetable kingdom; it may be extracted from acorns, chestnuts, horse-chestnuts, apples, quinces, wheat, barley, rye, peas, and beans; from the leaves of the cabbage, cress, hemlock, borage, and saffron; from the berries of the elder, the juice of the grape, &c.; it is, however, contained in the greatest quantity in the grain of wheat, and it is from this that it is usually procured.

In order to extract gluten, the flour of wheat must be kneaded into a paste with water; this paste must be afterwards worked by the hand under a stream of water from a spout, till the liquid flows off clear; the starch, sugar, and all the other principles contained in wheat, which are soluble in water, are thus carried off, and there remains in the hands only a soft, elastic, glutinous, ductile, semi-transparent substance, adhering to the fingers after it has lost its moisture, and exhaling an animal odor; this substance is called gluten or the *vegeto-animal* principle.

Gluten is destitute of taste, turns brown in the air, and putrefies in the same manner as animal substances do; it is insoluble in alcohol, and but slightly soluble in water. Combustion and distillation disengage from it the same products as those furnished by animal matter.

Wheat is composed almost entirely of starch and gluten. The results of the analyses made by Davy, of the wheat of different countries is as follows:

100 parts of fall wheat of excellent quality gave of

starch	77
gluten	19

100 parts of spring wheat

starch	70
gluten	24

100 parts of Barbary wheat

starch	74
gluten	23

100 parts of Sicily wheat

starch	75
gluten	21

The wheat of southern countries contains more gluten than that of the northern countries; and the hard-grained wheat more than the soft-grained wheat of the same country. That wheat which contains the most gluten, ferments the most easily when made into dough; it is for this reason that the Italian pastes are made of the flour of the hard wheat from the Crimea, instead of that from the wheat of the north.

Amongst all the different kinds of bread corn, those from the flour of which the best bread is made, and of which the dough *rises* or ferments the most readily, are those which contain the most gluten: they may be ranked in the following order.

1. Wheat, containing from $\frac{18}{100}$ to $\frac{20}{100}$ of its weight of gluten.
2. Barley, from $\frac{5}{100}$ to $\frac{8}{100}$
3. Rye, from $\frac{1}{200}$ to $\frac{1}{100}$
4. Oats, from $\frac{1}{200}$ to $\frac{2}{100}$

When grain or flour has undergone any change by which the gluten is destroyed, the bread made from it is bad and unwholesome, and such grain or flour should only be employed for making starch.

Flour which contains but little gluten, or which has been deprived of it, if made into bread, turns sour by fermentation; the dough does not rise, and when baked is acid, heavy, and indigestible.

There are some very nutritive vegetables in which the starch, instead of being combined with gluten, as it is in the bread corns, is united with mucilage; this is the case in peas, beans, and potatoes. The flour of these will not alone make bread; but it is frequently used in years of scarcity, mixed with that of wheat, to increase the quantity of bread. Dough made of flour thus mixed does not ferment so completely, as that made entirely from wheat flour; the bread, however, is well tasted and wholesome, and preserves its freshness for even a longer time than the other.

ARTICLE IX.

Tannin.

Tannin, or the astringent principle, is contained in a great variety of vegetables; it is of a brown color, highly astringent, and dissolves readily both in water and alcobol. Its predominant characteristic is that of affording an insoluble precipitate when added to a solution of gelatine. It combines with a solution of iron, and forms a black precipitate. It enters into the composition of writing ink, and of the greater part of the black dyes for cloth.

Tannin cannot be procured perfectly pure without a great deal of difficulty, and the operations require a degree of nicety which can only be acquired by a close acquaintance with chymical manipulation. For the greater part of the purposes to which it is applied it is not requisite that it should be freed from all foreign substances. The great affinity which tannin has for gelatine causes it to combine with that principle whenever presented to it, till the substances containing the gelatine are completely exhausted of it: the various proportions of tannin contained in the different kinds of bark used in the manufacture of leather are determined from this circumstance.

The most important purpose to which tannin is applied is that of converting skins into leather, and for this purpose the tannin contained in the bark of the oak is generally preferred. In this process layers of ground bark are placed alternately with layers of skins in a pit, the layers of bark being slightly moistened in order that the tannin may act readily. As the tannin combines with the gelatine of the skin, the latter changes its color to a reddish brown, and its opacity and consistency are at the same time increased, till by the progress of the operation the change is carried on through the whole substance of the skin, and it is thus brought to the firmness of leather. This new combination, which consists entirely of a union of tannin and gelatine, is compact and resists putrefaction; it can be cut with a knife by quick strokes, and employed for numerous purposes.

The best leather is that which, by being allowed to remain in the pit a long time, is formed gradually: in this case the slowness with which the combination takes place renders it more close and complete, than when the tannin is dissolved in water and the skins plunged into it. By this last process the thickest skin may be tanned in a few days, but the quality of the leather will be very inferior.

An astonishing improvement has been made in the art of tanning since M. Seguin discovered that it consisted entirely in producing an union of the astringent principle with the gelatine, which constitutes nearly the whole substance of skins: since this fact has been ascertained, tanners make use of the liquor of tan which has been once applied, but of which the strength is not exhausted, to moisten the bark in the pits, by which the operation is accelerated, without any injury to the product, and leather is thus formed in three or four months, as completely as it would be in eighteen by the use of the bark in a nearly dry powder.

Dry skins generally increase about one third part of their weight by tanning. The different kinds of bark used in tanning bestow various shades of color upon the leather produced.

Tannin has a strong affinity for coloring principles, so that in many cases it serves as a mordant in stamping; it is not then surprising that leather should retain the colors it receives so strongly.

ARTICLE X.

The Vegetable Acids.

I HAVE already observed, that when the proportions of oxygen combined with hydrogen are more than sufficient for the formation of water, the vegetable product will have an acid character. It can therefore be a matter of but little surprise, that we find acids so abundant in the vegetable kingdom.

The quantity of acid contained in plants varies greatly during the several stages of vegetation, and according to the circumstances by which the developement of the individual is influenced. Plants raised in the shade, or which grow in cloudy, cold, or rainy seasons, when the transpiration of carbonic acid by the leaves cannot be carried on for want of the action of the direct solar rays, by which alone it is produced, accumulate the acid in their vessels, and consequently all their products partake of the same general character. The greater part of fruits are sour before arriving at maturity; but this is owing to the fact, that the mucilage and sugar, which are afterwards found in them, are not yet sufficiently developed to correct the acid and disagreeable taste.

The vegetable acids which are found most extensively diffused in vegetables are the oxalic, citric, tartaric, benzoic, gallic, acetic, malic, prussic, &c. The analysis of vegetables presents a great number of acids, but as they are found only in particular kinds of plants, and their uses are either very limited, or altogether unknown, I do not think it necesary to make here an enumeration of them.

Most acids are crystallizable, and some of them can be brought into a concrete state as soon as they are separated from the other principles with which they are combined in the plant. Vinegar, or the acetic acid, crystallizes when highly concentrated; M. Mollerat prepared crystals of it as transparent as ice.

Oxalic acid crystallizes in the form of four-sided prisms: the acid of commerce presents this appearance. M. Deyeux has found it free in the hulls of the chick pea, and it has likewise been extracted from the expressed liquor of the plant: it exists in the stalks and leaves of sorrel, and in the juice of all the varieties of rhubarb.

It may be produced by the action of nitric acid upon most vegetable substances, especially sugar.

Oxalic acid is soluble in water and alcohol; cold water dissolves one half of its own weight; boiling water a weight equal to its own; and alcohol $\frac{66}{100}$ of its own weight.

This acid possesses a strong affinity for the metallic oxides, especially those of iron; it has also the characteristic property of depriving other acids of lime combined with them, and of forming with it an insoluble salt; and it is upon these qualities that its use in the arts is principally founded.

Oxalic acid thrown into water containing any calcareous salt, causes the liquor to become turbid, and forms from it a deposit which is found to be the oxalate of lime. If the oxalate of ammonia be made use of for the above purpose, the action will be more speedy than if the oxalic acid be used pure; because decomposition is accelerated by the exchange of principles constituting the two salts.

The power which oxalic acid possesses of dissolving readily the oxide of iron, renders it exceedingly useful in the manufacture of stamped goods, especially of cotton cloths. In this process the whole fabric is covered with a mordant of iron, which is afterwards removed by means of this acid combined with gum, so that the color applied adheres firmly only to those parts where the mordant has not been destroyed: this process is conducted with far more ease than that which was formerly practised, of applying the mordant with the block, reserving those parts untouched which were not to receive a fixed color.

The oxalic acid is better than any other for removing ink spots from cloth: it is only necessary for this purpose to put a little upon the spot, and to moisten it with a drop of water, after which a slight rubbing with the hand and a little rinsing in pure water removes every vestige of the stain.

Messrs. Gay-Lussac and Thénard obtained, from an analysis of oxalic acid, carbon, oxygen, and hydrogen, in the following proportions.

100 parts of oxalic acid,

Carbon	26.566
Oxygen	70.689
Hydrogen	2.745*

Tartaric acid may be extracted from the juice of the mulberry, grape, currant, &c. This acid is almost always found in vegetables combined with potassa, with which it forms a nearly insoluble salt: it is this union which occasions it to be so easily precipitated from the liquors in which it is contained, especially when they ferment. The coats of tartar which are found deposited upon the sides of casks are a combination of tartaric acid, potassa, and extractive matter.

When tartar and the lees of wine are burned together, they leave a light, grayish, alkaline residuum, known in commerce under the name of *tartarated ashes;* this product has its particular use in the arts.

The crystallized substance known in commerce, and extensively used, under the name of *cream of tartar*, is prepared by dissolving tartar in water containing pipe-clay; this solution, after having been filtrated, is carefully evaporated till crystallization takes place; a part of the extractive matter of the tartar is separated and falls to the bottom of the vessel, the rest remains in solution. The crystals thus obtained are composed of potassa with an

[* By the best analysis no hydrogen is found in oxalic acids. — Tr.]

excess of tartaric acid ; when exposed to the air upon cloths they acquire a brilliant whiteness.

From this last combination tartaric acid may be extracted by the following process, for which we are indebted to Scheele. Dissolve cream of tartar in boiling water, and saturate the solution with chalk ; a precipitate of lime combined with the acid will be thrown down ; this must be separated, and sulphuric acid poured upon it in the proportion of one third of the weight of cream of tartar employed ; to this mixture apply a gentle heat for ten or twelve hours ; the sulphuric acid will combine with the lime and form an insoluble precipitate, whilst the tartaric acid will be set free and swim above it ; the whole must then be diluted with cold water, and the liquor filtrated and evaporated to the consistency of a sirup, when the tartaric acid will be precipitated in a concrete state. When evaporation is carried on slowly and the sirup allowed to remain at rest, the acid crystallizes in long octahedrons : if these crystals be purified by being repeatedly dissolved, and the solution filtrated and evaporated, they become very white, and present the form of tetrahedral prisms, terminated by pyramids of four elongated faces.

Tartaric acid is composed of

Carbon	24.050
Oxygen	69.321
Hydrogen	6.629

One of the acids most extensively found in the vegetable kingdom is the malic ; this differs essentially from the two of which I have just spoken, in remaining always in a liquid state, and forming with lime a salt soluble in water.

Malic acid may be procured by saturating the juice of apples with potassa, and decomposing the salt thus formed by means of the acetate of lead : the precipitate thus produced must be washed, after which sulphuric acid must be poured upon it till the liquor retains no sweetish taste : an insoluble sulphate of lead is formed, which may be separated from the malic acid by filtration. Scheele, by whom this acid was discovered, has made many experiments to ascertain its existence in vegetables.

Malic acid is found most abundantly in apples, barberries, plums, and sour grapes ; red fruits furnish less of it, but it is found in a greater or less quantity in nearly all the products of vegetation.

This acid exists naturally in all wines, but it is more abundant in those of the north than in those of the south; it predominates in them when made of unripe grapes, or if the must have been badly fermented. White grapes contain less malic acid than red ones, and I believe the superiority of the liquor obtained from the first ought to be referred to this difference. Brandy made from wine abounding in this acid, turns vegetable blues red, and is of a bad quality. Malic acid has not as yet been made use of in the arts.

Citric acid is found in large quantities in oranges and lemons, particularly in the last; the skins of wild, hairy plums, the red currant, cherries, strawberries, and raspberries likewise contain it; in these it is found united with malic acid in nearly equal proportions.

The process given us by Scheele for obtaining and crystallizing citric acid, is the one we still make use of; the acid is saturated with lime, and the insoluble salt thus formed is decomposed by sulphuric acid diluted with water; the liquor is then evaporated and the acid obtained in a crystalline form: by being repeatedly dissolved, filtrated, and evaporated, the crystals are produced in the form of rhomboidal prisms, of which the inclined planes are terminated at each end by a summit of four trapezoidal faces.

In Sicily and some other countries where lemons grow in profusion, it is customary to extract the juice of the fruit and saturate it with lime; this citrate is afterwards sent to the places where it is to be consumed, and there the operation of extracting the acid is terminated. The great quantity of mucilage which the juice of the lemon contains, prevents it from being kept for a long time, or conveyed to any considerable distance, without undergoing changes that affect its nature.

The process of pressing the lemons is begun in November, and ended in March: the quantity of juice extracted depends on the ripeness of the fruit. The liquor is put into barrels, and either sent off, or what is preferable, sold on the spot to individuals engaged in manufacturing it into the citrate of lime, in order to prevent the decomposition, which exports of this nature always undergo.

About $\frac{1}{20}$ of carbonate of lime is required to saturate a given weight of lemon juice: the citrate is carefully washed, and after being dried is sent to its place of destination.

When nothing more than the extraction of the citric acid is required, the process is conducted in the following manner. Sulphuric acid diluted with six or seven times its weight of water is thrown upon the citrate, the mixture being stirred as the citrate is turned in; when decomposition has fully taken place, the citric acid swims above the insoluble sulphate of lime which has been formed; the whole is filtrated and the deposit washed; the water of the washing is added to the acid, and evaporation is carried on in pewter vessels: this operation may be commenced by boiling the liquor rapidly, but in proportion as this becomes thickened the action must be diminished; when the acid has acquired the consistency of a sirup it is removed from the fire and left to crystallize. After the crystals have been removed from the *mother water*, ten or twelve times its own weight of water is added to it, and it is then treated in the same manner as the lemon juice.

In order to obtain the crystals of citric acid perfectly pure, it is necessary to repeat the processes of solution, filtration, and evaporation, several times. When these operations are skilfully performed, the juice of the lemon yields about $\frac{1}{7}$ of its weight in citrate of lime, and $\frac{1}{13}$ of citric acid in crystals.

Citric acid is very soluble in water, and advantageously supplies the place of lemon juice for domestic purposes, and in the arts, both by its being freed from mucilage, which renders the juice liable to undergo speedy changes, and from the diminution of its bulk by concentration.

To give a flavor to food, citric acid is much more agreeable than vinegar, on account of the aromatic particles it contains; dissolved in water it forms a very wholesome drink: about 30 grains of this acid dissolved in a pint of water and sweetened with sugar, composes an excellent lemonade. From its refreshing and antiputrescent properties, it is invaluable during the hot months, and especially as an article for sea stores of vessels in warm latitudes.

Citric acid has also its peculiar uses in the arts; like the oxalic acid, it is employed in forming *reserves* in printed goods, and in removing spots of ink or rust.

When the coloring principle of the saffron (*carthamus tinctorius*) is dissolved by an alkali and precipitated by citric acid, it produces, upon silk, an orange, scarlet, or light-red color; when thrown down in the same manner upon a white, oily surface, it constitutes the vegetable red or *rouge*.

The constituent principles of citric acid are found in the following proportions;

Carbon	33.811
Hydrogen	6.330
Oxygen	59.859

Acetic acid exists ready formed in the sap of plants; it is sufficiently distinguished from all the other vegetable acids by the peculiar property it possesses of forming easily soluble salts with the earths and alkalies.

When a plant or any other vegetable product is distilled, not only the acetic acid which it contains is extracted from it, but a great quantity of acid is formed by that decomposition and disunion of the constituent principles, which is produced by heat. The smoke which escapes from our fire-places is only a confused mixture of water, acetic acid, oil, carbonic acid, and carbon.

The acid produced by combustion and distillation has been known for a long time under the name of pyroligneous acid: it was not suspected to be the same as vinegar.

A vast quantity of this acid may be procured with great ease by the new method of carbonizing wood in close vessels: the acid thus procured is however combined with oil, which gives it a dark brown color, and a disagreeable empyreumatic odor; but by a particular process it may be freed from all foreign matter, and rendered perfectly pure: to effect this, the acid must be saturated with lime or an alkali; after which the oil must be carbonized by exposing the new salt impregnated with it, to a degree of heat sufficient to effect that change; the salt is then to be decomposed by pouring upon it sulphuric acid; or, the same result may be obtained by decomposing the acetate of lime by means of an alkaline sulphate: in this case an exchange of bases takes place, and the acetate treated with sulphuric acid furnishes a very pure acid.*

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* Wood is distilled in a great iron retort, the bottom of which is of cast iron, and the sides of thick sheet iron; when it is filled with wood the lid of it is carefully luted on with clay.

For distillation the wood must be very dry and the sticks prepared of equal thickness. Each retort will contain two "*voies*" (= 106 cubic feet) of wood. The opening or flue by which the smoke escapes, is placed at a distance of some inches from the bottom of the boiler or retort. The acid is carried by copper pipes into a vessel, in which the water is constantly renewed: the acid and tar flow by a cock into a close vessel. The inflammable gas passes through copper

The acid procured in this manner has some very great advantages over that obtained by the acidification of fermented liquors; this, being distilled, is consequently purified from any foreign substance, and can be thrown into the market in so concentrated a state, as to render it much more active than vinegar of wine, and capable of producing effects which it is difficult to obtain from that.

Even to the present day, all the acetic acid employed either for domestic purposes, or in the numerous operations carried on in the workshops of the various arts, has been provided by the degeneration or decomposition of fermented drinks, such as wine, beer, cider, perry, &c.: all these liquors are more or less spirituous, and contain a portion of mucilage, which tends continually to produce in them the acetous fermentation.

To prevent the acidification of wine, the liquor should be put up in good casks, well stopped, and placed in a cool place, of which the temperature does not sensibly vary;

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tubes into the fire-place, to heat the cylinder and increase the carbonization.

The process of carbonization lasts five hours; the cooling is completed in about seven.

The acid thus produced is very impure, but serves for the preparation of pyrolignites of iron: in order to purify it, it must be put into an iron boiler, saturated while cold with chalk, and the tar, which will rise to the top, skimmed off; the liquor must then be poured into another boiler, heated to ebullition, and the saturation continued up to this point; sulphate of soda is afterward added, when there is formed sulphate of lime, which is precipitated, and acetate of soda, which remains in solution. The liquor must then be drawn off and evaporated till pellicles are formed, when it is thrown into large tubs, where it acquires solidity by cooling.

An igneous fusion of this mass has been produced by heating it in a cast-iron boiler, till the water was all evaporated, and afterwards continuing the fusion to ignition; the liquor was then poured into moulds in which it solidified; in this state it is black, and easily soluble in hot water: a solution of it well filtrated and evaporated yields crystals of acetate of soda, which retain almost nothing of the empyreumatic odor. When these crystals are dissolved in water, and the solution decomposed by sulphuric acid, crystals of sulphate of soda are obtained, and acetic acid, which only requires distillation to be perfectly pure; the acid then marks from eight to ten degrees of the aërometer of Baumé, (= specific gravity of 1.060 to 1.075.) To obtain the acid in a crystalline state, it is sufficient to combine it with lime, and to decompose by sulphuric acid this salt slightly calcined: the sulphate of lime takes nearly all the water which remains in the acetate.

The *mother water* of the first operations, evaporated to dryness and mixed with tar, serves as a combustible; the ashes passed through a reverberatory furnace and afterwards leached affords very fine subcarbonate of soda.

it should be clarified in order to free it from the mucilage, which would cause it to ferment; and care must be taken so to place the casks, that the liquor will not be liable, by being jolted, or shaken, to have the mucilage, which has been precipitated, mixed again with it.

When wine has been well fermented, and all its mucilage decomposed or precipitated, it is no longer capable of turning sour. I have kept some of the red wine of the south in uncorked bottles, upon a terrace exposed to the heat of the sun during a whole summer, without its undergoing any other change than that of completely losing its color; the coloring principle being precipitated in the form of pellicles or membranes, which remained swimming in the liquor. Towards the end of August, I put into two of these bottles, containing equal quantities, the juice of two apples, and at the end of a month the liquor was converted into vinegar.

The care which is necessary to preserve wine unchanged, indicates the course to be pursued for converting it into vinegar: all that is required to accomplish this, is to expose the liquor to the air at a temperature of between 70° and 80° Fahrenheit: when the liquor does not contain any fermentative matter, a portion of yeast may be added to it; or it may be put into casks, which are impregnated with acetic acid or which contain sour lees.

I shall not undertake to enumerate the various uses to which vinegar is applied upon our tables, or in our kitchens; its employment in the arts is at least as extensive and as varied; aromatic plants are distilled with it for perfumes, and it is used for dissolving iron, copper, lead, and alumine, to form mordants in dyeing, and colors in stamping.

Messrs. Gay-Lussac and Thénard found acetic acid to contain carbon, oxygen, and hydrogen in the following proportions;

Carbon	50.224
Hydrogen	5.629
Oxygen	44.147

Prussic Acid. Bitter almonds, peach stones, and the leaves of the laurel, when distilled, afford an acid, which forms, with a solution of iron and a small quantity of alkali, a greenish blue precipitate: this acid bears a strong resemblance to that which is extracted from some animal substances, and which, when combined with iron, forms Prussian blue.

M. Gay-Lussac, who has made a series of experiments upon prussic acid, found it to consist of carbon, azote, and hydrogen, combined in the following proportions;

Carbon	44.39
Azote	51.71
Hydrogen	3.90

The two first elements of this composition form a radical, which our distinguished author calls *cyanogen:* the combination of this with hydrogen constitutes the *prussic* or *hydrocyanic acid.* There exists in this acid no trace of oxygen, nor is it the only instance of the kind, which modern chymistry affords us.

Combined with iron, prussic acid forms the valuable substance known by the name of Prussian blue, the use of which is so important in coloring and painting. M. Raymond has discovered a method of fixing this color so successfully upon silk, that indigo has almost disappeared from the coloring establishments of Lyons: a son of M. Raymond has been equally successful in his use of it for woollen manufactures.

The vegetable kingdom furnishes many other acids, as the benzoic, gallic, mucic, kinic, &c.; but as they are less abundant, and their uses very limited, I do not think it necessary to give here any account of them.

ARTICLE XI.

The Fixed Alkalies.

Potash is found, in greater or less quantities, in all vegetables; soda generally in plants growing near the sea, or in soils impregnated with marine salt.

The most convenient mode of obtaining potash is by burning vegetable substances, leaching the ashes, and evaporating a solution of them to dryness: this first product is known under the name of *salts*, and is employed in the arts; it is colored, but becomes white by being calcined in a reverberating furnace; it is then known by the name of *pearlash.*

As the use of the salts and of pearlash in the arts is very extensive, and as there are few localities where they may not be advantageously made, I have been of opinion, that a farmer might easily unite the manufacture of them to his agricultural labors, and thus increase the income arising from his lands: I shall therefore enter into some details respecting it.

All plants do not yield the same quantity of ashes, nor do equal weights of the ashes of different plants afford the same quantity of potash. Of the comparative value of certain vegetables, we may judge from the following Tables, prepared from the experiments of Messrs. the Superintendents-general of the powder and salt-petre works, for the year 1779, and from those of Messrs. Kirwan, Pertuis, and Vauquelin.

Results of the Experiments made by Messrs. the Superintendents-general.

Names of vegetables.	Quantity of vegetable burned.	Product in ashes.	Weight of ley.	Weight of salt produced.	Color of the salt.
Box	800 lb.	23 lb.	216 lb.	1 lb. 12 oz. 6 gr.	Lead ore.
Oak	915	12	124	1 " 6 " 4	Gridelin.
Beech	887	5 $\frac{1}{30}$	66	1 " 4 " 6	Coffee with milk.
Yoke elm . . .	981	11	216	1 " 3 " 5	Grayish white.
Elm	1028	24	300	3 " 15 " 0	Wine gray.
Aspen	648	8	120	0 " 7 " 6	Deep black.
Fir	730	2 $\frac{1}{2}$	80	0 " 7 " 0	Rusty black.
Bramble	800	27	276	4 " 10 " 4	Whitish gray.
Turnsol	200	20 $\frac{3}{4}$	333	4 " 0 " 0	Yellowish white.
Turkey wheat . .	440	39	612	7 " 12 " 1	Ash color.

The salt obtained by these operations loses by calcination, in order to convert it into pearlash, 25 or 30 per cent. of its weight.

The results of the experiments made by Kirwan upon 1000 lbs. of each of the vegetables assayed, are as follows.

Name of the vegetable.	Product in ashes.	Product in alkali.
Stalks of maize . . .	88.00	17.05
Giant sun-flower . . .	57.02	20.00
Branches of the vine . .	34.00	5.05
Box	29.00	2.26
Willow	28.00	2.85
Elm	23.05	3.09
Oak	13.05	1.05
Aspen	12.02	0.74
Beech	5.08	1.27
Fir	3.04	0.45
Fern, in August . . .	36.46	4.25
Wormwood	97.44	73.00
Fumitory	219.00	79.00

Table of Mean Results of the Experiments of Messrs. Kirwan, Vauquelin, and Pertuis, upon 10,000 *parts of each plant.*

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

In selecting plants to burn for potash, it is advisable to choose those that contain the most of it; grasses, leaves, the stalks of French beans, of peas, melons, gourds, cabbages, artichokes, potatoes, maize, and garget, are very rich in this alkali. The plants are first dried, and then burned, and the ashes leached.

The operation is very simple: a tub is filled with ashes, upon which water is thrown till it stands upon the top; in the course of a few hours the water filtrates through the ashes, and flows off by a vent in the bottom of the tub: this ley should mark 10° or 12° of the aërometer of Baumé. (Sp. gr. 1.075 to 1.091.) The first leaching does not exhaust the ashes entirely of all their alkali, and fresh water is therefore passed through them till they contain nothing soluble: this weak ley is added to new ashes, till it acquires a suitable degree of strength.

The leached ashes form an excellent manure for damp or clayey soils; and it is used advantageously in the manufacture of black glass.

Ley is most readily formed by using hot water, but I have confined myself to pointing out the simplest means for accomplishing the purpose, and those that require the least apparatus.

The ley is a solution of potash, which may be extracted from it by evaporation: this process may be commenced in a copper boiler, into which a very fine stream of the ley should flow to replace that which evaporates: when the liquor has acquired the consistency of honey, it should be put into iron boilers to complete the operation. As the substance thickens, care must be taken to remove that portion of it which adheres to the sides, and to stir the whole carefully with iron spatulas. When the substance congeals and becomes solid upon being exposed to the air, it is poured into casks and thrown into commerce under the name of salts.

The whole process is simple, and may be conducted upon our farms without any difficulty. The farmer can appropriate to himself this branch of industry without interrupting the usual course of his labors: broom, heath, thistles, ferns, brambles, nettles, &c. may be collected during the days when agricultural business cannot go on, and in the *dead season*, and in the winter they may be burned, and the ashes leached.

I do not propose to any farmer to calcine the salts, to reduce them to real potash, because he would need for this purpose a reverberating furnace, and the process would be one at variance with his customary employments. The salts are already applied to numerous uses in the arts: if the manufacture of them should become a domestic one, there would very soon be establishments formed for converting the salts into pearlash, and thus extending the employment of it.

The *salts* and pearlash contain all the soluble salts that are found in ashes. M. Vauquelin, who has analyzed the various kinds of potash of commerce, with reference to the difference in their qualities, has obtained the following results. 1112 parts of each kind were subjected to experiment.

Potash.	Real quantity of alkali.	Sulphate of potassa.	Muriate of potassa.	Insoluble residuum.	Carbonic acid and water.
From Russia	772	65	5	56	234
From America	857	154	20	2	129
Pearlash	754	80	4	6	308
From Dantzick	603	152	14	79	304
From Vosges	444	148	10	34	304

The salts and pearlash are much used in the arts: they form the basis of the soft soaps, and enter into the composition of white glass: they are used in washing and bleaching: they are greatly employed in coloring, metallic castings, the manufacture of salt-petre and alum: in short, there are few manufacturing establishments, in which they are not consumed in greater or less quantities.

Soda exists in nearly all plants which grow in a soil impregnated with marine salt; but all of these do not furnish it equally pure, nor in the same quantity.

The barilla (the calsola vermiculata of Linnæus) is cultivated in Spain for the purpose of extracting from it the Alicant soda, which is one of the kinds most esteemed in commerce; in nearly all the other countries lying upon the sea or upon the salt lakes, the plants growing upon their coasts are burned, in order to obtain from them this substance. The different kinds of soda contain different quantities of alkali, according to the character of the plants from which they are procured; hence arises a great difference in their names, prices, and uses.

For the manufacture of soda, the marine plants are gathered at the season when their vegetation has terminated, and they are left to dry: a pit four feet square and three feet deep is dug in the earth; this is heated with split wood, and the saline plants are afterwards thrown gradually in: combustion is continued during seven or eight days; the ashes become fused in the pit, and remain in this state till the end of the process: when the combustion is completed, the whole is allowed to cool, and then the block of soda is divided into large pieces for the market.

I have always observed that when this mass of soda bubbles up in the pit, there escape from the surface jets of flame which appear to arise entirely from the combustion of *sodium;* the perfect resemblance which the flame bears to that of the burning metal, struck me very forcibly when I saw sodium burned for the first time.

The plants which are most commonly burned for obtaining soda, upon the borders of the Mediterranean and of the ocean, are the *salicornia europea*, the *salsola tragus*, the *statice limonium*, the *triplex portulacoïdes*, the *salsola kali*, the *wareck*, &c. The soda which is afforded by some of these is of a middling quality: the richest in alkali is the salicornia; in some of them it does not exist sensibly; these abound in muriate and sulphate of soda mixed and strongly (*frittés*) fused with lime, silica, alumina, and magnesia; the soda extracted from these plants, though weak, has nevertheless its use in the arts; it is employed in glass works, where, by means of the lime it contains, and the charcoal which is made to enter into the composition for making glass, the sulphate of soda is decomposed, and the salt being left free promotes the fusion of the earthy substances. When soda contains 10 or 12 per cent. of alkali, it serves to make weak leys in the soap manufactories.

In addition to the soda procured by the combustion of marine plants, chymistry furnishes us with the means of supplying it to commerce by the decomposition of the muriate of soda or marine salt; this is converted into a sulphate by means of sulphuric acid, and the last formed salt afterward decomposed in a reverberatory furnace, in which it is mixed with charcoal and chalk.

The soda of commerce is never pure; it contains at the utmost but 30 or 40 per cent. of alkali: a solution of it evaporated, yields octahedral crystals with rhomboidal bases; these crystals consist of alkali and carbonic acid.

In order that soda may possess all the requisite strength, it is necessary to separate it from the carbonic acid with which it is always united, and by which its properties are weakened. This is easily done by mixing quick-lime with a solution of soda. The acid has so strong an affinity for lime as to quit the soda to combine with it. The ley procured from this mixture is caustic, and leaves a burning impression upon the tongue: the soda thus purified acts more readily upon the bodies with which it combines. This mode of preparation is indispensable when soda is to be employed with oil in the manufactory of hard soap; it is useless when it is to be combined at a strong heat with earthy bodies, as is the case in glass works.

Davy discovered soda and potash to be metallic oxides, or burnt metals; and Berzelius has proved that when these two alkalies are pure, potash is composed of $\frac{17}{100}$ of oxygen, and $\frac{83}{100}$ of potassium, and that soda was the result of 74.42 of sodium in 100 parts, and 25.58 of oxygen.

Besides the substances of which I have spoken, plants contain certain salts, earths, and metallic oxides, which have never been extracted, either for domestic purposes or to be employed in manufactures: the existence of these is however so constant, their proportions so little varied in the same kind of plant, and their situations in the different parts of vegetables so marked, that they must be regarded as belonging essentially to vegetation, and not as being introduced accidentally and without design into the organs of the bodies in which they are found.

The most abundant salts in plants are the sulphate of potash, and common salt, the phosphates of lime, and the nitrate of potash: the sulphate and muriate of soda do not exist in any considerable quantity, excepting in marine plants.

Of the four earths procured from these plants by combustion, the one most extensively found is silica; next to that comes lime, and afterwards magnesia and alumina.

M. Th. de Saussure, in his highly valuable work upon vegetation, has given us the results of the analytical investigations he has made for determining the quantity of ashes, salts, earths, and metallic oxides, which are furnished by an equal weight of a great variety of vegetables: these results are as follows.

Names of Plants.	Ashes contained in 100 parts of green plants.	Ashes contained in 100 parts of dry plants.
1. Leaves of the oak, (*quercus robur*,) of the 10th of May	13	53
2. The same of the 27th of September .	24	55
3. Stems or branches of young oaks stripped of their bark, 10th of May . . .	"	4
4. Bark of the above-mentioned branches .	"	60
5. Wood of the oak separated from the alburnum	"	2
6. Alburnum of the wood above-mentioned .	"	4
7. Bark of the trunks of the oaks above-mentioned	"	60
8. Liber of the above-mentioned bark . .	"	73
9. Extract of the wood of the above-mentioned oak	"	61
10. Mould of oak wood	"	41
11. Extract of the above mould . . .	"	111
12. Leaves of the poplar, (*populus nigra*,) of the 26th of May	23	66
13. Leaves of the same of the 12th of September	41	93
14. Trunks of the same poplars stripped of their bark, September 12th	"	8
15. Bark of the same trunks	"	72
16. Leaves of the nut tree, (*coryllus avellana*,) of the 1st of May	"	61
17. The same washed with cold distilled water	"	57
18. Leaves of the nut tree of the 22d of June	28	62
19. The same of the 20th of September .	31	70
20. Branches of the same tree stripped of their bark, 1st of May	"	5
21. Bark of the same branches	"	62
22. Wood of the Spanish mulberry tree, (*morus nigra*,) separated from the bark, November	"	7
23. Alburnum of the same	"	13
24. Bark of the above branches . . .	"	89
25. Liber of the bark	"	88
26. Wood of the yoke elm, (*carpinus betulus*,) separated from the alburnum . .	4	6
27. Alburnum of the above	4	7
28. Bark of the same	88	137
29. Trunks, and branches stripped of their leaves, of the chestnut, (*æsculus hippocastanum*,) 10th of May	"	35

Water of vegetation in 100 parts of the plants when green.	Salts soluble in water.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
745	47	24	0.12	3	0.64	25.24
549	17	18.25	23	14.5	1.75	25.5
"	26	28.5	18.25	0.12	1	32.58
"	7	4.5	63.25	0.25	1.75	22.75
"	38.6	4.5	32	2	2.25	20.65
"	32	24	11	7.5	2	23.5
"	7	3	66	1.5	2	21.5
"	7	3.75	65	0.5	1	22.75
"	51	" "	" "	" "	" "	" "
"	24	10.5	10	32	14	8.5
"	66	" "	" "	" "	" "	" "
652	36	15	29	5	1.25	15.75
565	26	7	36	11.5	1.5	18
"	26	16.75	27	3.3	1.5	24.5
"	6	5.3	60	4	1.5	23.2
"	26	23.3	22	2.5	1.5	24.7
"	8.2	19.5	44.1	4	2	22.5
655	22.7	14	29	11.3	1.5	21.5
557	11	12	36	22	2	17
"	24.5	35	8	0.25	0.12	32.2
"	12.5	5.5	54	0.25	1.75	26
"	21	5.25	56	0.12	0.25	20.38
"	26	27.25	24	1	0.25	21.5
"	7	8.5	45	15.25	1.12	23.13
"	10	16.5	48	0.12	1	24.38
346	22	23	26	0.12	2.25	26.63
390	18	36	15	1	1	29
346	4.5	4.5	59	1.5	0.12	30.88
"	9.5	" "	" "	" "	" "	" "

Names of Plants.	Ashes contained in 100 parts of green plants.	Ashes contained in 100 parts of dry plants.
30. Leaves of the chestnut, 10th of May .	16	72
31. The same of the 23d of July . . .	29	84
32. The same of the 27th of September .	31	86
33. Flowers of the same	9	71
34. Ripe fruits of the same, 5th of October .	12	34
35. Pea vines, (*pisum sativum*,) in flower .	"	95
36. The same bearing ripe seeds . . .	"	81
37. Plants of the marsh bean, (*vicia fabia*,) before flowering, 23d of May . . .	16	150
38. The same whilst in flower, 23d of June	20	122
39. The same bearing their ripe seeds . .	"	66
40. The same separate from their ripe seeds	"	115
41. Seeds of the same	"	33
42. Bean plants in blossom, raised from seeds of the same kind, and watered with distilled water	"	39
43. Golden rod, (*solidago vulgaris*,) before flowering	"	92
44. The same when ready to flower, 15th of July	"	57
45. The same bearing ripe seeds, 20th of September	"	50
46. Plants of the turnsol, (*helianthus annuus*,) of the 23d of June, one month before flowering	"	147
47. The same when beginning to flower, 23d of July	13	137
48. The same of the 20th of September, bearing their ripe seeds	23	93
49. Plants of wheat, (*triticum sativum*,) in flower	"	"
50. The same bearing ripe seeds . . .	"	"
51. The same one month before flowering .	"	79
52. The same when it flowers, 14th of June	16	54
53. The same of the 28th of July, bearing ripe seed	"	33
54. Straw of the above wheat separated from the seed	"	43
55. Kernels selected from the above wheat .	"	13
56. Wheat bran	"	52
57. Plants of maize, (*zea mais*,) of the 23d of June, one month before flowering . . .	"	122
58. The same of July 23d, in flower . .	"	81

Water of vegetation in 100 parts of the plants when green.	Salts soluble in water.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
782	50	" "	" "	" "	" "	" "
652	24	" "	" "	" "	" "	" "
636	13.5	" "	" "	" "	" "	" "
873	50	" "	" "	" "	" "	" "
647	75	10.5	" "	0.75	0.5	13.25
"	49.8	17.25	6	2.3	1	24.65
"	34.25	22	14	11	2.5	17.25
895	55.5	14.5	3.5	1.5	0.5	24.50
876	55.5	13.5	4.12	1.5	0.5	24.38
"	50	17.75	4	1.75	0.5	26
"	42	5.75	36	1.75	1	12.9
"	69.28	27.92	" "	" "	0.5	2.3
"	60.1	30	" "	" "	0.5	9.4
"	67.5	10.75	1.5	1.5	0.75	18.25
"	59	8.5	9.25	1.5	0.75	21
"	48	11	17.25	3.5	1.5	18.75
"	63	6.7	11.56	1.5	0.12	16.67
877	61	6	12.5	1.5	0.12	18.78
753	51.5	22.5	4	3.75	0.5	17.75
"	43.25	12.75	0.25	32	0.5	12.25
"	11	15	0.25	54	1	18.75
"	60	11.5	0.25	12.5	0.25	15.5
699	41	10.75	0.25	26	0.5	21.5
"	10	11.75	0.25	51	0.75	23
"	22.5	6.2	1	61.5	1	78
"	47.16	44.5	" "	0.5	0.25	7.6
"	4.16	46.5	" "	0.5	0.25	8.6
"	69	5.75	0.25	7.5	0.25	17
"	69	6	0.25	7.5	0.25	17

Names of Plants.	Ashes contained in 100 parts of green plants.	Ashes contained in 100 parts of dry plants.
59. Plants of maize bearing ripe grain . .	"	46
60. Stalks of the same separated from their ripe ears	"	84
61. Ears of the above stalks	"	16
62. Kernels of the above maize . . .	"	10
63. Straw of barley, (*hordeum vulgare*,) separated from its ripe seeds	"	42
64. Grains of barley from the above straw .	"	18
65. Grain of barley	"	"
66. Oats	"	31
67. Leaves of the rose-bay, (*rhododendrum ferrugineum*,) growing upon Jura, a calcareous mountain, June 20th	"	30
68. The same growing upon Breven, a granitic mountain, 27th of June	"	25
69. Stalks and branches of the rose-bay growing upon Jura, 20th of June	"	8
70. Stems of the rose-bay from Breven, 27th of June	"	8
71. Leaves of the pine, (*pinus abies*,) growing upon Jura, June 20th	"	29
72. The same growing upon Breven, June 27th	"	29
73. Branches of the pine stripped of leaves, June 20th	"	15
74. A variety of whortleberry, (*vaccinium myrtillus*,) growing upon Jura, August 29th	"	26
75. The same growing upon Breven, August 20th	"	22

Water of vegetation in 100 parts of the plants when green.	Salts soluble in water.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
"	" "	" "	" "	" "	" "	" "
"	72.45	5	1	18	0.5	3.5
"	" "	" "	" "	" "	" "	" "
"	62	36	" "	1	0.12	0.88
"	20	7.75	12.5	57	0.5	2.25
"	29	32.5	" "	35.5	0.25	2.8
"	22	22	" "	21	0.12	29.88
"	1	24	" "	60	0.25	14.75
"	23	14	43.25	0.75	3.25	15.63
"	21.1	16.75	16.75	2	5.77	31.52
"	22.5	10	39	0 5	5.4	22.48
"	24	11.5	29	1	11	24.5
"	16	12.27	43.5	2.5	1.6	24.13
"	15	12	29	19	5.5	19.5
"	15	" "	" "	" "	" "	" "
"	17	18	42	1.5	3.12	19.38
"	24	22	22	5	9.5	17.5

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CHAPTER X.

ON THE PRESERVATION OF ANIMAL AND VEGETABLE SUBSTANCES.

Each product of agriculture has its season; there are few which the earth yields at all times. From this well-known truth there result two incontestable facts; the first of these is, that in the years of abundance the production is greater than the consumption, and consequently a part is lost, and the remainder sold at a low price; the second is, that the consumption of the greater part of the articles of agricultural produce takes place within one year, whilst, if the agriculturist had sure means of preserving them, it might be prolonged indefinitely, and thus the sale of them rendered more profitable. The question of the best manner in which the productions of the earth may be preserved, is then one of the most important to be solved in rural economy.

Before making known the processes by which, as we have learned from experience, agricultural products may be preserved free from change, it is necessary to cast a glance upon the causes by which that change is produced.

The natures of all bodies which have ceased to live or vegetate are changed, as soon as the physical or chymical laws by which they were governed, cease to act; the elements of which they were composed then form new combinations, and consequently new substances.

Whilst an animal lives, or a plant vegetates, the laws of chymical affinity are continually modified in its organs by the laws of vitality; but when the animal or plant ceases to live, it becomes entirely subject to the laws of chymical affinity, by which alone its decomposition is effected.

The principles of the atmospheric air which is imbibed by the organs of living bodies, whether animal or vegetable, are decomposed and assimilated by them, whilst dead bodies are decomposed by its action. Heat is the most powerful stimulant of the vital functions, yet it becomes after death one of the most active agents in the work of destruction. Our efforts, then, for the preservation of bodies ought to be directed to counteracting or governing those chymical or physical agents, from the action of which they suffer; and we shall see that all the methods which have been successful, are those which have been formed upon this principle.

The chymical agents, which exert the most powerful influence over the products of the earth, are air, water, and heat; the action of these, however, is not equally powerful over all classes of plants; the soft and watery, and those which approach the nearest to animal matter, decompose most readily; the principles of such are less coherent, less strongly united than of others; so that the action of disorganizing agents upon them is prompt and effectual.

All the methods now employed for the preservation of bodies, consist in so far changing their nature, as to deprive them of the elements of destruction contained within their own organs; or in secluding the substances to be preserved from contact with the destructive agents mentioned in the preceding paragraph; or in causing them to imbibe certain other substances, the anti-putrescent qualities of which counteract all action, whether of internal or external agents.

ARTICLE I.

On the Preservation of the Fruits of the Earth by Drying.

In all vegetable products, water exists in two different states, one part of it being found free, and the other in a state of true combination: the first portion, not being confined except by the covering of the vegetable, evaporates at the temperature of the atmosphere; the second is set free only at a temperature sufficiently high to decompose the substances containing it: the first, though foreign to the composition of the vegetable, enters into every part of it, dissolving some of its principles, serving as a vehicle for air and heat, and being converted by cold into ice; by these several properties it greatly facilitates decomposition: the second portion, from which no evil of the kind arises, is found combined and solidified in the plants, and its action is thus neutralized. Drying, then, consists in depriving the product to be preserved of the water contained in it in a free state, by heat; and from what has been observed above, it follows, that too great a degree of heat must not be applied, as, in consequence, the taste and the organization of the substance would be changed by a commencement of the decomposition of its constituent principles: the temperature should never be higher than from 35° to 45° of the centigrade. (= from 95° to 113° Fahrenheit.)

Drying can be performed either by the heat of the sun or in stove rooms. In the southern climates the heat of the sun is sufficiently powerful to dry the greater part of the fruits, and thus to preserve them unaltered: the drying is effected by exposing them to the rays of the sun upon hurdles or slates, where they will be protected from rain, dust, and injury from animals. Practice alone is sufficient to enable one to judge of the degree, to which each kind of fruit must be dried in order to its preservation.

When the outer skin or rind of the fruit is of a kind to prevent the water from passing off freely, incisions are made in the rind to facilitate its evaporation. In this manner are prepared most of the dried fruits, which form so considerable an article of commerce between the south and north.

Those fruits which contain much sugar, as prunes, figs, musk grapes, &c., may be prepared in the above manner, and preserve nearly all their qualities, but the acid fruits acquire a disagreeable sharp taste by the concentration of the juices; some of them, however, may be kept advantageously in this way.

In the hottest countries the process of drying is often commenced by subjecting the fruits to the heat of an oven, after which they are exposed to the sun; some kinds of fruits are thrown into a weak ley, till their surface becomes wrinkled, when they are taken out, carefully washed in cold water, and afterwards dried in the sun: cherries particularly are treated in this manner. When the heat of the sun is not sufficiently great to evaporate all the water contained in the pulp of large, fleshy fruits, they may be cut in pieces and then dried; in this manner apples and pears are prepared for keeping.*

But this method is neither speedy nor economical enough

[* In this country, apples, pumpkins, squashes, and peaches are kept by drying.—Tr.]

for such preparations as have but little value in commerce, and which can never supply, for domestic purposes, the place of those whole fruits, which may be easily preserved from one season to another: it is therefore customary to perform the drying either in stove rooms or ovens. In the first case, the fruits, after being cut, are placed upon hurdles arranged in rows in a chamber heated to 112°: in the second, the fruits are put into an oven, from which bread has just been drawn; this is repeated if the fruits be not sufficiently dried the first time.

Some of the fruits referred to above, may be dried without being cut: of this kind are the tender pears, which cannot be preserved fresh through the winter; such as the rousselet, the butter pear, the doyenné, the messire-jean, the martinsec, &c. These are first peeled, and then thrown into boiling water, after which they are put upon hurdles into an oven heated less than is required for bread; after an interval of three or four days the pears are again exposed to the same degree of heat, having been, however, first flattened between the palms of the hands; whence they have acquired the name of *pressed pears.*

Fruits prepared in either of the above ways are susceptible of fermentation upon being soaked in water, and they thus serve to make a cheap and useful drink.

In those countries where these fruits abound, the drying of them is commenced about the 1st of August, and those are made use of, which then fall from the trees; in autumn, when the harvest is gathered in, the soundest and finest fruits are carefully selected to be used fresh, whilst the rest are dried and preserved in a place free from moisture, to be employed in making drinks. I shall in another chapter speak of the processes by which this is effected.

The herbage, which serves as food for domestic animals, can be preserved only by drying, and this in all countries is practised at the time of cutting. Fodder, which is imprudently stacked up whilst still damp, ferments, and the heat thus produced is sufficient to change the quality, produce mouldiness, and is sometimes even great enough to set the whole on fire.

There are some fruits, which may, by a few slight precautions, be preserved throughout the year. The first of these precautions is, that of depriving their surface of all moisture before putting them up; and the second consists in keeping them in dry places, where the temperature will constantly be between 50° and 54° Fahrenheit; the third, in separating the fruits, so that they shall not come in contact; I have seen apples preserved in this manner eighteen months. It is necessary to be particular in selecting fruit for preservation; that only should be taken which is perfectly sound.

Wood and other portions of vegetables, and various animal substances, are likewise preserved by drying; this process increases their hardness and renders them less accessible to the action of air, insects, and other destructive agents.

The process of drying is not confined to preserving fruits from decomposition: it furnishes the means of securing their juices unaltered for the formation of extracts of them.

When the juices of plants can be extracted by pressure alone, it is only necessary to evaporate these juices at a due degree of heat and in suitable vessels, till, being deprived of all the water which retained them in a liquid state, they are reduced to dryness. Evaporation, if continued for a long time at the temperature of boiling water, changes these juices a little; the albumen, which is contained more or less abundantly in all sweet fruits, is coagulated, and after this they are no longer susceptible of undergoing the vinous fermentation.

The must of grapes, operated upon in this manner, furnishes an extract called *raisiné*, which is an article of food both wholesome and agreeable, and which, when soaked in water, decays without producing alcohol. The fermentative power of this substance may, however, be restored by mixing with it a little of the yeast of beer, as this repairs the loss, which the juices had sustained by heat during evaporation.

All the juices obtained from sweet fruits may be converted into extracts, and thus furnish agreeable food: the quality of the extract varies according to the quantity of sugar contained in the fruit, and the care taken in the operation: when the juices are several times clarified, and evaporation carried on in a water bath, care being taken to stir the liquid to prevent its adhering to the sides, the color and taste of the extract or jelly obtained is far superior to that procured without employing these precautions.

The sweetest fruits, however, even the well ripened grapes of the south, contain a portion of acid, which, when concentrated by evaporation, acts upon the copper boilers in which the operation is carried on, so as to form an acetate of copper: this, by producing colics, would render the use of the extract dangerous, especially at the south, where the principal article of food for children is the *raisiné*. In order to obviate this serious evil, an ancient and generally followed custom is observed: as soon as the must of the grapes begins to boil in the coppers, a bunch of keys is thrown in, and allowed to remain till the operation is completed: these keys attract the copper and become covered with the precipitate thus formed, and nothing remains in the extract but the acetate of iron, which is not injurious.

I have observed that the juices of all succulent fruits might be converted into extracts, and thus preserved for use in the course of the year; but the greater part of these juices, when concentrated by evaporation, are so excessively acid as to be totally unfit for food, and they only form, when mixed with water, a very sour drink. In order to correct or conceal this acidity, these juices are boiled with an equal weight of sugar, and thus made into sirups and jellies.

As it is of importance to be able to extract and preserve for domestic purposes, for pharmacy, and for the arts, certain vegetable products, which can be only very imperfectly obtained by mechanical pressure, recourse is had to other means; those liquids are made use of which will dissolve the wished for principles, and the solution is afterwards evaporated to dryness.

The fluid most generally employed for solutions is water; this dissolves the extractive matter, mucilage, sugar, and the greater part of the salts, and mixes with the mealy portions of plants; it may be applied cold or hot to the vegetables, or they may be boiled in it, according to the nature of the principle to be extracted; water will dissolve all that is soluble in them, and the extracts may be obtained from the solution by evaporation.

The resins, which are found so abundantly in some vegetables, are not soluble in water, and the place of this liquid must be supplied by alcohol, in which the plant must be digested; evaporation will separate the alcohol from the resin which it holds in solution. In order to avoid the accidents that might occur from the dispersion in the atmosphere of a very inflammable vapor, the evaporation must be so conducted that the dissolvent may be received into an alembic or close vessel.

In addition to the methods of preserving fruits by drying, and by reducing their juices to the state of sirups and jellies by natural or artificial heat, M. de Montgolfin has applied the action of the air pump with great success. I have tasted juices prepared and thickened in this manner, and I thought they were much superior to those that had been evaporated in either of the modes hitherto usually practised. I do not doubt that, when this method becomes better known, it will be generally adopted.

ARTICLE II.

On the Preservation of the Fruits of the Earth by Secluding them from the Action of Air, Water, and Heat.

The atmospheric air coming in contact with fruits deprives them of their carbon, and forms carbonic acid.

Fruits exposed to the solvent action of water suffer decomposition by having the affinity existing between their constituent principles weakened, and at length destroyed.

Heat dilates the particles of bodies, and thus diminishes the forces of cohesion and attraction, and favors the admission of air and water.

The combined action of these three agents produces very speedy decomposition; the effect produced by any one of them is slower, and the results different. So that in order to preserve fruits from decomposition it is necessary to guard them from the power of these three destroyers.

In several European countries, particularly in the north, roots of all kinds are preserved merely by secluding them entirely from air, heat and water; this is done by digging deep ditches in a dry soil upon a spot a little elevated, and depositing in them the roots, which are afterwards covered over with a layer of earth, of sufficient thickness to prevent them from suffering by the frost; over the whole is then laid a bed of straw, broom, or fern, in order to protect them from rain and from the water of melting snows which might filtrate through into the pit.

Roots, to keep well, must have their surfaces entirely free from moisture before being thus buried.

The roots have in themselves a preserving principle, which does not exist in a dead plant or one that has terminated its period of vegetation: they have as yet lived but a portion of their vegetable life; they have not formed the seeds, which secure the continuance of their species; and to fulfil this great design of nature they profit by every circumstance, which can favor and confirm their vegetation; but when placed for a time beyond the action of air, water, and heat, their organs remain at rest till again excited by the presence of these powerful agents.

As dead bodies do not retain this animating principle, the energies of which are only suspended in roots, grains, &c. during the winter, so they suffer decomposition, though less rapidly, from the contact of air, heat, and water.

In the way of which I have just spoken, beets, carrots, potatoes, and many other vegetables may be preserved uninjured till summer.

A very simple method of preserving them at least free from decomposition, is, to heap them up in piles upon a very dry soil, and then to cover them upon all sides with straw enough to protect them from rain and frost: in England this is esteemed the best method of keeping turnips.

Vegetables may likewise be preserved by heaping them up in barns to the height of five or six feet, care being taken to cover them well with straw or hay at the commencement of the severe cold weather. Should the roots in these heaps begin to vegetate, they must be removed, and thus their farther developement checked.

Thomas Dallas has published some very important observations * upon the modes of treating potatoes which have been affected by the frost. With us such potatoes are rejected, as being unfit either for food or for furnishing fecula. The able agriculturist above mentioned considers them in three different states; 1st, when they are slightly touched by the frost; 2d, when the outer portion of their substance is frozen; and 3d, when they are frozen throughout.

In the first case he finds that nothing more is necessary, than to sprinkle the roots with lime to absorb the water form-

* Bibliothèque Universelle, Art. *Agriculture*. Vol. II. p. 123.

ed under the skin, which would speedily occasion their complete decomposition. In the second instance he causes the potatoes to be pared and thrown for some hours into water slightly salted. When the potatoes are completely frozen, he finds them to yield, upon distillation, a spirituous liquor resembling the best rum, and affording much more alcohol, and that of a better quality, than can be procured from the roots before freezing.

The preservation of grains has always been an object of much consideration both to governments and agriculturists, and it is a peculiarly interesting one, because bread forms so large a portion of the nourishment of Europeans, and because the scarcity and high price of it have been the cause or the pretext for popular discontents and insurrections.

The art of preserving grains unchanged, besides obviating this evil, presents the additional advantage to the agriculturist of enabling him to make a good harvest compensate for a bad one, by maintaining the price of bread stuff at a rate suitable alike for the consumer and the producer; and thus avoiding those periodical successions of high and low prices, of abundance or scarcity, which disturb social order, and give rise to excesses prejudicial to all.

It appears that the people of the most ancient times preserved their grains uninjured through several years, merely by secluding them entirely from the action of air and moisture.

The Chinese have from time immemorial preserved their grains in pits, which they call *teon:* these ditches are either hewn out in rocks free from chinks and humidity, or what is still better, they are dug in a firm, dry soil. If there be any danger of humidity about the pits, they are lined with straw, or wood is burned in them to harden and dry the earth. The grain is not put into the pits till some months after the harvest, nor till it has been well dried in the sun; it is then covered over with mats made of the chaff of the grain or of straw, and this again by a bed of earth well beaten down, that it may not be penetrated by water.

Varro, Columella, and Pliny inform us, that the ancients preserved their grain in ditches hollowed out of rocks or dug in the earth, the sides of them being lined with straw. Quintus Curtius relates, that the army of Alexander experienced great privation upon the banks of the Oxus, because the inhabitants of the country preserved their corn in subterranean pits, the situation of which was known only to those who dug them.*

I have several times had occasion to visit in Amboise what are called Cæsar's granaries, and from examining the place, I think there can be no doubt that it was intended for the preservation of grain. About thirty feet above the level of the waters of the Loire, there are dug in a dry and solid calcareous rock, deep and broad excavations arranged in three stages separated from each other by vaults. Behind the first excavations, there are formed others, and separated from them by a wall of rock six or seven feet thick, and within these are built, of brick and mortar, circular granaries of about fifteen feet in diameter: the upper part of the granaries is contracted, and the aperture, which is that by which they are filled, is covered over by a stone: the grain is taken from them through a hopper placed at the bottom. To avoid all dampness, the space contained between the walls of the granaries and those of the rock is filled with fine and very dry sand from the Loire. A gallery formed also in the rock communicates on one side with the granaries, and on the other with a staircase cut in the rock, which conducts directly to the banks of the river. It would seem that the excavations served as magazines of stores for daily consumption, and the granaries for reserved supplies. It is difficult to conceive of any arrangement more suitable for preserving grain, or of a situation more favorable for obtaining or for transporting it.

In some warm and dry countries, it has been customary from time immemorial to preserve grain, with less precaution certainly than in the granaries above described, but in situations where it could be kept for six or seven years. Prosper Alpinus relates, that not far from Cairo there was a high wall built, enclosing a spot of ground of about two miles in circumference, which was filled every six or seven years with heaps of wheat: he adds, that the abundant dews of night softened the outer portions of the grain and caused it to germinate, but that in a short time the sun dried the young shoots, which then formed a hard covering to the mass, and did not permit either air or

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* *Des Fosses propres à la Conservation des Grains;* par M. le comte de Lasteyrie.

moisture to penetrate it. In a similar manner individuals may preserve their grain upon floors in the open air, merely by covering the heaps of it with mats.

In the Basilicata, according to the report of Intieri,* the farmers form their corn into heaps upon the borders of the sea; these are soon covered, in consequence of the rains, with a strong vegetation, which forms over them a layer impermeable by air or water.

There is a curious account given by Joinville, of the manner in which supplies of provisions for the army which St. Louis conducted in person to Jerusalem, were secured.

"Quant nous venimes en Cypre, le Roy estoit ja en Cypre, et trouvames grant foison de la pourvéance le Roy; c'est à savoir, les celiers le Roy et les deniers et les garniers. Les celiers le Roy estoient tiex, que sa gent avoient fait en mi les champs sur la rive de la mer, gran moyes de tonniaus de vin, que il avoient acheté de deux ans devant que le Roy venist, et les avoient mis les uns sus les autres, et que quant l'en les véoit devant, il sembloit que ce feussent granches. Les fourmens et les orges *il les r'avoient mis* par monciaus en mi les champs; et quant en les véoit, il sembloit que ce feussent montaignes; car la pluie qui avoit batu les blez de lonc temps, les avoit fait germer par desus, si que il n'i paroit que l'erbe vert.

"Or avint ainsi que quant *en les vot mener en Egypte*, l'en abati les crotes de desus à tout l'erbe vert, et trouva l'en le fourment et l'orge aussi frez comme l'en l'eust maintenant batu." †

This method of preservation is undoubtedly less costly than that of digging ditches; but there is in it some loss of

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* *Della perfetta Conservazione del Grano;* 4to. page 12.

† "When we came to Cyprus, the king was already there, and we found great abundance of stores collected by him; the cellars of the king and his treasures and granaries were as follows. The cellars of the king, which his people had made in the midst of the fields upon the borders of the sea, were three in number, stocked with great casks of wine, bought two years before the king's arrival; the cellars were placed one over the other, so that when viewed in front they looked like barns. The wheat and the barley they had put in heaps in the midst of the fields, and these appeared like mountains, for the rain had moistened the corn for a long time, and caused it to germinate on the outside, so that nothing was seen but the green herb.

"Now when we had determined to carry the grain into Egypt, and the outer crust was removed from the heaps of grain, the wheat and barley were found as fresh as if but now piled up."

History of St. Louis. Paris. 1761. folio. pp. 28 and 29.

grain, nor can the rest be so securely kept for several years as it would be in pits. The custom however has long prevailed, and is still to be found throughout Europe, and even in Asia and Africa.

The grains which are consumed in Algiers and Tunis, or which are exported thence, are, after having been well dried in the sun, deposited in trenches cut in the rocks, and having their sides lined with straw. The Count of Lasteyrie has found the same mode followed in Malta, Sicily, Spain, and Italy. There are even some countries where the governments have caused trenches to be constructed, in which the cultivators of lands might deposit their harvest till a favorable season for selling them.

In order to secure a perfect preservation of the grain in trenches, it is necessary to make use of certain precautions, without which the entire loss of it must be hazarded: the means of security are as follows.

1st. The grain should never be put into trenches till it is perfectly dry; it must therefore be first exposed to the sun for several days, and during that time be often turned, that every part of it may become equally dry.

2d. In constructing the trenches, choice must be made of a dry soil, or a rock free from chinks, that there may be no danger either from dampness or the filtration of water. The walls of the trenches may be made with such cement as the Romans used in the construction of their aqueducts; this is composed merely of lime and pebbles; the walls of these aqueducts were raised in frames, and the surface of them carefully polished; I have visited the remains of some of them in various parts of France, and have found them everywhere present the same appearance: I am convinced that this cement is impenetrable by water, and of a solidity more than sufficient for constructing the sides of trenches.*

3d. The third precaution consists in excluding the air completely; if this fluid should gain admittance, it must necessarily convey in at the same time moisture and oxygen, the two principles of germination; the presence of air will likewise favor the existence and multiplication of insects; whilst if the trench be full of grain, and well closed, all the air which it contains will be changed into

* The mode of building may be used which the Count of Lasteyrie has proposed in his work, entitled *Des Fosses pour la Conservation des Grains.*

carbonic acid, (as I have explained in speaking of the action of air upon fruits,) and the insects will remain torpid. This last assertion is, as we shall shortly see, supported by the results of the experiments which have been made by the Board of Provisions of War, for the purpose of ascertaining the best mode of preserving grain.

But the construction of these trenches, as it involves some expense, and requires much care, will be for a long time rejected by mere farmers. However advantageous this arrangement may be, it belongs entirely to public authorities, great cities, and governments, to set an example of the use of it, by withdrawing from circulation, during years of abundant harvests, large quantities of corn to be deposited in trenches and preserved against years of scarcity. Much has been written, within a few years, upon the best methods of preserving grain ; but all those that have been proposed were founded upon the same principles.

The Board of Provisions of War, under the direction of Count Déjean, has performed a series of well-directed experiments, from which excellent results have been obtained : the apparatus used in them consisted of lead receivers hermetically sealed and having all their joinings soldered. Meal and grain full of weevils were enclosed in three receivers ; when these were opened, at the end of a year, it was found that no injury had been done by the weevils ; they were all either dead or in a state of torpor. In one of the receivers there was found a collection of grains adhering to each other in a mass about as large as a middling-sized apple : this arose from the entrance of air and moisture through a hole the size of a pin, accidentally left unsoldered in one of the joints.

The elder M. Ternaux caused trenches to be formed and filled with corn in the beautiful field of Saint Arven ; in order to be sure of the preservation of the grain, he caused the trenches to be opened from year to year, and the results were always satisfactory.

Corn, well dried and guarded from air and moisture, may be preserved in the ear for a long time, and it is a well-known fact that in some agricultural countries the sheaves are formed into stacks which are taken down either for consumption or the market, at those times when the laborers upon the farm can be employed only in threshing in a barn.

Instead of constructing trenches of stone without the farm buildings, there might be built, within them, bins of stone, of a size proportioned to the produce of the farm, and with the openings covered in such a manner as to exclude the air. The same purpose may be answered by chests and tubs of wood having their outsides covered with a thick coat of oil paint. The great earthen jars in which oil is kept at the south, are likewise very good for keeping grain in.

Either of these methods is preferable to that of storing grain in such granaries as are commonly used, since the utmost care will not entirely protect it from moisture, insects, mice, &c., nor will it often remain in them unchanged beyond three or four years.

Corn which is housed without being thoroughly dried, or which is stored in a damp place, acquires a musty smell and taste, which render it unfit for the customary uses: but as this alteration affects only the outer covering, and not the substance of the kernel, it may be easily removed by throwing upon the grain double its weight of boiling water, carefully stirring the mass till the water becomes cold. The spoiled kernels, which swim upon the top, must then be removed, the water poured off, and the grain spread to dry. M. Peschier preferred employing for this purpose boiling water rendered slightly alkaline, and afterwards washing the grain in pure water.*

When corn has been heated or injured in a perceptible manner, the vegeto-animal portion is almost always changed; in this case the farina is not susceptible of a good fermentation, and the bread made from it is unwholesome: such grain is fit only for the manufactory of starch.

The modes of preserving vegetable juices and other articles of food deserve also much attention.

The substances of which I shall now speak present the alimentary principle so mixed with, or dissolved in the aqueous fluid, as to render them exceedingly susceptible of alteration and decomposition. It is not sufficient to seclude these from the air, since they contain for the most part within themselves those principles of fermentation, which, acting upon each other, produce decomposition.

Seclusion from the air alone will not preserve these substances; the nature of some of the fermentative principles must be changed; and for effecting this I would recom-

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* *Annales de Chimie et de Physique*, tome VI. page 87.

mend the preserving process made use of by M. Appert, and confirmed by numberless experiments. I shall here only make mention of the mode of preservation ; as the work of M Appert is before the public, it may be consulted in regard to the necessary details respecting each operation.*

The process consists,

1st. In putting up, in glass jars or bottles, those solid or liquid substances which are to be preserved.

2dly. In corking the bottles carefully.

3dly. In placing these vessels upright in a boiler filled with cold water, as high as the ring of the bottles.

4thly. In causing the water to boil, and continuing the ebullition for a longer or shorter time, according to the nature of the substance contained in the vessels.

In this process we see that nothing more is required than a boiler and some bottles or jars ; it is one that may be practised in the smallest domestic establishment. In order however to avoid accidents and insure success, certain precautions in each part of the process are necessary : the principal of these, especially those that are indispensable, I shall here point out.

The choice of bottles is a matter of some consequence : the form of the champagne bottles is the best, and as the glass of these is of a more uniform thickness than that of others, it is generally better annealed ; these bottles then should be preferred, particularly if they have proved their soundness by having resisted the action of the compressed air contained in foaming wine.

Too much care cannot be taken in the choice of corks ; only the superfine should be used, and these should be free from defects. The length of the corks should be at least eighteen or twenty lines, and the diameter a little greater than that of the mouth of the bottles, into which they must be forced by blows of a mallet.

The bottles must be filled within three inches of the ring ; the corks selected for them must be softened a little in water ; in stopping a bottle, put the small end of the cork into the mouth of the bottle, and force it in as far as possible with the hand ; then wrap the bottle in a towel, and, holding the neck of it firmly in the left hand, drive

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* *Le Livre de tous les Ménages, ou L'Art de conserver pendant plusieurs années toutes les Substances Animales et Végétales.* 1811, 2e édition ; par M. Appert.

the cork in by repeated blows with a mallet; a few lines of the length of the cork must be left beyond the mouth of the bottle to receive the wire or twine with which it is to be secured. Each bottle is then to be put into a bag of strong linen, which will cover it to the cork, and placed in a boiler filled with water to the rings of the bottles. The boiler is to be covered, and over the lid must be placed a damp linen cloth, to secure the retention of the heat. The apparatus being thus prepared, the water may be heated to boiling, and continued in that state as long as the nature of the substance to be preserved requires.

When the fire has been removed from the fire-place a quarter of an hour, the water must be drawn off by means of a siphon, or of a stop-cock placed near the bottom of the boiler; the cover must not be removed to take out the bottles till fifteen minutes after the water has been drawn off.*

When meat or other solid food is to be preserved, wide-mouthed bottles or jars may be used in the same manner as the narrow-necked bottles mentioned above. Good

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[* The translator of this work has preserved the most delicate fruit by a process somewhat similar to the one here described, but with one pretty important difference. As the preservation of the fruit seems to depend wholly upon the exclusion of the air, which would not be effected by corking the bottles before exposing them to heat, and as the bottles would be in great danger of being burst by the expansion of the air contained not only in the fruits themselves, but in the interstices which must unavoidably occur between them, the above method appears to be an imperfect one; she therefore takes the liberty of inserting in this note the process which she has used successfully, and particularly as she has found fruit thus preserved exceedingly grateful in sickness at those seasons of the year when no fresh fruit could be procured, and when that which was done with sugar was neither suitable nor agreeable.

Pick carefully over the fruit to be bottled so as to take only such as is perfectly sound, and put it in bottles having wide mouths with closely fitting corks, shake the fruit well down so as to leave as little space unoccupied as possible in the bottles; when they are quite full, set them *uncorked* into a boiler of cold water over the fire, raise the temperature of the water as quickly as possible to the boiling point, and as soon as ebullition takes place, put the corks into the bottles, and remove them from the boiler; some ready melted cement, such as is commonly used for closing bottles, must be immediately applied over the corks, and the fruit having been freed by the heat from the air contained within the bottles will thus be protected from the action of the external air, and may be preserved fresh for many months.—Tr.]

gravy of meat, and beef three quarters cooked, when prepared according to the foregoing directions, have been found as good after being eighteen months at sea, as when first put up. Attention must be paid in putting up solid articles in bottles, to pack them closely, in order that as little air as possible may interpose between the pieces. *Consommés*, strong decoctions,* and jellies of meat containing all those portions of it most nourishing to man, may be thus preserved uninjured for a long time.

Before milk is put into bottles for keeping, it should be evaporated in a water or vapor bath, and the scum which forms upon the top carefully removed; half an hour before evaporation is completed, there should be mixed with every pint of the reduced milk, the yolk of an egg well beaten. After being thoroughly cooled the milk must be put into bottles, and corked tightly, to undergo the second scalding. Milk preserved in this way has been found at the end of two years to be unchanged, and to afford butter and butter-milk the same as if new. It is not however pretended, that it preserves all the qualities of new milk; it almost always has a peculiar odor and taste, but such as it is, it forms an agreeable and a valuable article for sea stores for long voyages.

Cream evaporated one fifth part and put into bottles after having had the skin coagulated upon the surface removed from it, and then subjected to a second scalding for an hour, has not been sensibly altered at the end of two years.

Those vegetables of which so much use is made in all families, may be preserved in the same manner; they are, however, boiled a shorter time, and some of them must previously undergo a degree of preparation. For instance, in preserving asparagus it is necessary, after having washed it, to plunge it first into boiling and then into cold water, to deprive it of its acrid taste; it afterwards receives but a slight scalding.

To preserve the color of the small bush-beans, bottles filled with them are plunged into very cold water, where they remain for an hour; they are then drawn out, corked, wired, and scalded for an hour. Artichokes, after having had boiling water poured over them, are washed in cold water, drained, and scalded in the bottles for an hour.

* Answering to "portable soups."

Cauliflowers are prepared in the same way as artichokes, excepting that they are boiled but half an hour. Legumes in general, prepared and seasoned, and put into bottles when three quarters cooked, will keep very well with being scalded twenty minutes.

Antiscorbutic plants, and the juices which are extracted from all fruits and vegetables, require only to be scalded. When juices are to be kept, they should be carefully strained and clarified ; plants require to be well washed, picked and dried, and to be crowded into the bottles. When any of these preparations are made use of, they should be dressed in such a manner as to give them the appearance of those prepared daily in our kitchens.

Those articles that have been cooked before being put into bottles, only require to be heated.

The strong decoctions will need the addition of nothing but water to become good broth.

The jellies of beef, veal, mutton, chickens, &c., when diluted with water, and seasoned with salt, make excellent soups.

The legumes must be washed upon being taken from the bottles, and then prepared as if fresh.

The juices may be appropriated as usual, either for food, drink, or medicine.

I shall close this article by observing, that some bodies are preserved from destruction, and guarded from the attacks of insects, and the action of air and water, by means of a coat of varnish laid upon the surface of them ; this practice has become very common, and when the varnish is applied to bodies well dried, and does not scale off, it preserves them a long time. Oil paints and tar produce the same effect.

The custom of preserving eggs by immersing them in lime water has lately been introduced into Paris ; the shell of the egg thus immersed becomes covered with a thin coat of lime, which preserves its contents unchanged.

ARTICLE III.

On the Preservation of certain Articles of Food by means of Salt and Spirituous Liquors.

Most of the articles employed as food, or other domestic purposes, may be prepared by the following methods.

1. By immersing them in liquids which will not dissolve them, and which will not themselves be changed by time.

2. By combining them with other bodies with which they form indestructible compounds.

3. By saturating them with salts.

In the first method the liquor usually employed is either alcohol or brandy; many other fluids, as the acids, oil, &c., might be made use of, but these alter the taste, and change the qualities of the greater part of the substances, which are designed for food. Nearly all kinds of fruit may be preserved in alcohol, but it is used only for those of small size, as it cannot penetrate throughout the substance of the larger kinds, and consequently they are liable to decay ; I shall therefore mention only the modes of preserving cherries and plums in brandy.

The juice of six pounds of early and very ripe cherries put into a sauce-pan, with three pounds of powdered sugar, is set over a fire and made to boil for half an hour ; the sauce-pan is then removed from the fire, and a pound of ripe raspberries is thrown into the liquor and pressed down with a skimmer ; to the whole is added six pints of brandy flavored with some aromatic, such as cloves, cinnamon, vanilla, &c. This preparation is preserved in close jars set in the sun.

As soon as the large cherries are ripe, the preparation of brandy, mentioned in the last paragraph, is to be strained and then put into glass jars filled with the fruit to be preserved ; these jars are placed on windows exposed to the sun, till the fruit becomes penetrated by the liquor.

Plums are prepared in a somewhat different manner. For preserving, take the finest green gages, prick them, and put them into a sauce-pan with cold water ; set the sauce-pan on the fire, and as fast as the plums rise, remove them with a skimmer, and throw them into cold water ; dissolve two pounds of sugar in two pounds of hot water, and when the sirup is cold, throw the plums into it, and allow them to remain in it at a gentle heat for some time; when the fruit is penetrated by the sugar, remove it, evaporate the sirup, put the fruit again into it, and treat it as before; after which, remove it again, and evaporate the sirup till it becomes tenacious, then return the plums to it for the last time. When the whole is cold, put it into bottles with a quantity of brandy equal to that of the plums and sirup. The unbroken plums alone must be put up in this way.

The description of this process is a sufficient guide for those, who wish to preserve other fruits in the same way.

When sirups are used instead of sugar, a greater quantity of brandy than that mentioned is necessary to preserve the fruits unchanged.

Alcohol dissolves and retains the aroma of plants; it is only necessary to make an infusion of the plant or flower in alcohol, and afterwards to pass the liquor through a filter.

I do not hesitate to direct in this work certain methods of obtaining spirituous liquors, which, when used sparingly, appear to me to be serviceable in preserving the health of country people. I feel that I ought not to aim at giving these drinks the qualities required by the luxurious, and those of delicate and refined taste, but direct such methods of obtaining them as are consistent with the most rigid economy, and with the employment of such materials as every mistress of a family has within her control.

To make three pints of ratafia of nuts, crack two hundred apricot stones from which the pulp has been separated; spread the kernels in the sun, and after they are sufficiently dry, pound them in a mortar, and put them into a bottle with a quart of brandy; cork the bottle carefully and set it in the sun. After twenty days, strain the liquor and add to it a pound and a half of sugar dissolved in half a pint of water, or two pounds and a half of good sirup; if a portion of almonds be mixed with the apricot kernels, the flavor of the liquor will be improved.

Some ratafia is made of almonds alone; in this case the kernels are thrown into boiling water to deprive them of their outer skin; they are then bruised in a marble or wooden mortar, with a little water and sugar, and this paste is put into a bottle with brandy; after having been exposed several days to the sun, the liquor is strained, and a suitable portion of sirup added to it. Very good ratafia is made from almonds and the kernels of peaches pounded together.

The base of all liquors of this kind is brandy and sugar; the difference in their flavor arises from the aroma and other portions of vegetables incorporated with them.

The best mode of proceeding is, to prepare first a liquor, by dissolving eight pounds of sugar in three times its weight of water: this must be boiled and skimmed, and when all the sugar is dissolved, the liquor must be strained and put into a jug with ten pints of brandy, the jug carefully corked and set in a cool place. Into this liquor various substances calculated to gratify the taste and smell may be put; when a portion of it is to be used, it is to be poured into a saucepan, and after being slightly warmed, the flavoring designed for it is to be added.

For orange-flower water, make an infusion of the petals of the flower, filtrate it through paper, and add of sugar one eighth of the weight of the flowers.

When the liquor is to be flavored with citron, orange, bergamot, or lemon, the surface of the fruits may be grated with bits of sugar, which imbibe the volatile oil contained in small vessels in the rind, and the sugar thus saturated with aroma is dissolved in the liquor. Vanilla, cinnamon, and clove may be used for the same purpose.

Liquors are sometimes made with the juices of fruits well refined.

I will here give as an example the ratafia of *four fruits.*

After having expressed the juice from ten pounds of cherries, and as many of currants, five pounds of raspberries, and five pounds of black currants and of bitter cherries, add to each pint of the juice one pint of good brandy, and allow it to remain undisturbed twenty-four hours; at the end of that time strain the liquor and add to each pint of it eight ounces of sugar; six weeks after, the liquor must be again strained, and an additional flavor may be given it if desired, by adding to it a little cinnamon, or clove-water, pounded coriander seeds, or bitter almonds.

All animal substances may be preserved from putrefaction in alcohol; anatomical preparations and some entire animals are kept in this liquid; but it is necessary that the alcohol employed for this purpose be of the best kind to be found in commerce; if it should contain any considerable proportion of watery particles, those portions of animal matter which are soluble would be dissolved and corrupted. Care must likewise be taken that the jars, in which these substances are put, be hermetically sealed, as otherwise the alcohol will be lost by evaporation.

There is another way in which animals of a small size may be perfectly preserved by means of alcohol; of this I am convinced by some experiments which I have made with the most satisfactory results, upon birds, in the following manner. Having suspended the bird by the beak, the vent being secured by a thread, I fitted a little tunnel to the throat, and thus filled the crop and intestines with very pure alcohol; as soon as this was evaporated, I poured in a fresh portion, and repeated this till the flesh was as dry as tinder. In this way the form of an animal may be perfectly preserved.

The second means of preservation of which I spoke at the commencement of this article, consists in bringing these substances into union with such bodies as will form with them indestructible compounds. The conversion of skin into leather is the most striking instance I can bring of this process: this is done by causing the tannin of certain vegetables to combine with the gelatine, which forms nearly the whole substance of skin: from this union there results a hard, indestructible compound, preserving the original form of the skin, but with increased weight.

The third mode of preserving bodies, is to incorporate them with salts unalterable by the air, which, penetrating the whole tissue of the substance, prevent decomposition: this is the most valuable and generally practised method of preserving meat and fish, and the articles thus prepared form an extensive branch of commerce between different nations; a supply of food which would otherwise be wanting, is thus provided.

The best salted provisions were formerly furnished by Ireland, and that country still carries on a very extensive traffic in them, though the same methods practised there, have been adopted by the Danes and other nations. I shall here describe succinctly the modes made use of.*

For salting, the fattest oxen of from five to seven years old are chosen; before that age, the flesh has not sufficient firmness, and after that period, it is too hard.

When the animals have been driven from a distance,

* The fullest statements may be found in the work of M. Martfelt, translated from the Danish, by M. Bruun-Neergaard.

they are not killed till two days after their arrival, and in the interval are allowed only water: before being killed, they should be bled freely, that all the blood may be drawn out of the body; and even after using this precaution, it is necessary, when the meat is cut up, to remove the blood very carefully from the pieces.

The carcasses should not be cut up till the animals have been dead twenty-four hours, and when this is done, all the marrow must be carefully removed from the bones.

The salt employed should be perfectly clean, and of a fine and heavy kind: the fine salt of Portugal is esteemed the best.

The proportion of salt to meat should be in volume, as 24 to 100. If only the Lisbon salt be used, the proportion is as 2 to 7½: in general the proportion in weight is as 1 of salt to 6 of meat.

That the salt may penetrate the meat quickly, the salters have a leather guard or a glove shod with iron upon the right hand; this glove is composed of two or three pieces of sole-leather, united by nails with rough, broken heads; a strap of leather serves to keep it on, and it thus forms a sort of flesh-brush, with which the blood can be pressed out of the meat, and the salt rubbed into it. Each piece of meat passes through the hands of a series of salters, who execute upon it the same operation, and when it arrives at the last, who is the most experienced and skilful, he examines to see if there be any defect in it, any vein which requires to be opened; he corrects the defects, opens the veins, rubs in more salt, and throws it into the cask of salted pieces: in this it remains in the air eight or ten days, the salt penetrates into it, and is turned into brine: at the end of this time it is taken out and barrelled. After the meat is removed from the cask, the brine is thrown into a trough, and a layer of salt put at the bottom of the cask; upon this is placed a layer of meat, and thus alternately till the cask is full. Attention must be paid to putting the pieces of inferior quality at the bottom of the cask, those of the better kind in the middle, and the best at top. When the meat is all packed in, it must be pressed down with a weight of fifty pounds, and the cask closed.

There must afterwards be a hole bored in one end of the cask, to blow into, in order to be sure that it does not leak: if no air escapes, the hole is closed again: if the contrary be the case, the aperture through which it passes is sought for. When it is ascertained that the cask is in good order, the bung is taken out, and the brine turned in till the meat is saturated and covered: the less brine is required, the better will the meat keep.

After having allowed the barrels to remain five days, it is necessary to examine whether they are well filled with brine, and if not, it must be added till they can contain no more: they must then be again blown into to be certain that they can lose none, and then the operation is ended.

Tongues are salted in separate casks.

The manner in which pork is salted does not differ from that which I have just described as used for beef, excepting that the fat is rubbed less.

In Hamburg the art of smoking beef has been carried to a degree of perfection not attained elsewhere; and the smoked beef of Hamburg enjoys everywhere the highest reputation.

For this purpose the fattest cattle of Jutland and Holstein are preferred, and these must be of a middling age. The meat is salted with English salt; the stronger salts, as those of Portugal, deprive the meat of its natural taste, and as the process of smoking contributes to preserve it from injury, that of salting does not require so much care.

To preserve the red color of the meat as much as possible, a certain quantity of salt-petre is added to the English salt, and the meat is allowed to remain in it eight days before being smoked.

Fires of oak chips are built in cellars, from whence the smoke is conveyed by two chimneys into the fourth story, and thrown into a chamber by two openings placed the one opposite the other. The size of the chamber is proportioned to the quantity of meat to be smoked, but the ceiling is not raised more than five feet and a half from the floor. Above this chamber there is another made of boards, into which the smoke passes through a hole in the ceiling of the first, whence it escapes by openings formed in the sides. The pieces of meat are hung up in the first chamber, at the distance of a foot and a half from each other, and a fire is kept up night and day for a month or six weeks, according to the size of the pieces.

The sausages are suspended in the second chamber, and the largest of them allowed to remain there six or eight months.

In this process two means of preservation are combined:

the first is the action of salt, and the second that of the pyroligneous acid, which is furnished by combustion, and which constitutes by far the greater part of smoke: this acid, as I have found by repeated experiments, penetrates the meat and preserves it from putrefaction, but when employed alone, the meat becomes hard, and acquires a disagreeable blackish hue.

Animal substances, by being immersed in a weak acid, or in water acidulated with sulphuric acid, may be preserved a long time without undergoing putrefaction, but this process is not applicable to such as are designed for food.

Other salts may be employed as substitutes for marine salt; but besides being more costly, they are either injurious to the health, or give to the meat a disagreeable taste, of which it cannot be entirely deprived.

Butter is a valuable article of food, and forms a great resource for the inhabitants of the country; but in those regions where the extent and fertility of the pasture lands permits great numbers of horned cattle to be raised, it is impossible for them to consume all the butter they make, whilst it is fresh; and besides, as the quantity of butter made is not the same at all seasons of the year, it is necessary that some means should be resorted to of preserving it from becoming rancid, and this is done by salting it.

The choice of a kind of salt suitable for preserving butter is not a matter of less importance, than when it is used for salting meat. Only such should be used as has, by long exposure upon the edges of the salt-pans, lost all the deliquescent salts which combined with it; salt in this state is drier and purer, than the new salts extracted by evaporation from sea-water, and has neither the sharpness nor the bitterness which characterize these. But whatever salt is used, it is advisable that it be whitened and purified by the process commonly made use of in our kitchens; it must be dried in an oven, and afterwards pounded in a marble or wooden mortar.

Nothing more is requisite in salting butter, than to work it well, so that the salt may be equally distributed, and then to put it down in clean and dry stone jars. If it should be perceived, seven or eight days after, that the butter has shrunk so as to leave a vacancy around the sides of the pot, a brine must be prepared by saturating hot water with pure salt, and this when cold must be turned gradually upon the butter till every part of it is well covered: the pots are then to be set in a cool place till the butter is taken out and made into lumps for market or home consumption.

Another way in which butter may be preserved a long time, is, by melting it in a pot at a very low degree of heat, skimming from the surface a thin layer of curd which will form upon it, and when this no longer collects, withdrawing it to cool and harden.

When the juices of fruits are to be preserved for food, sugar is used instead of salt; this possesses the double advantage of correcting the acid of fruits, and of incorporating better with them. Sugar improves the quality of the juices as much as salt would injure them, and as this last cannot be extracted, they could not be used as articles of nourishment.

The preparations formed with sugar are jellies and sirups; the first are the most concentrated, and serve as food; the latter mix easily with water, and are generally employed as drinks.

After the juices are expressed, clarified, and strained, there must be added to them a suitable portion of sugar: most of them require an equal weight: they must then be boiled gently till sufficiently evaporated, and the operation completed by clarifying the liquor, which is thus rendered more agreeable to the eye.

CHAPTER XI.

OF MILK AND ITS PRODUCTS.

There is no product of a farm which contributes more towards the prosperity of the establishment than milk; not only does it form in itself one of the most important articles of food for the family, but the sale of a portion of it, either in its natural state, or made into butter or cheese, furnishes a daily income, from which nearly all the internal wants of a household may be supplied: I therefore think it will not be departing from my subject to devote one chapter in this work to an object of so much importance. Milk appears to me to be one of the least animalized portions of the animal kingdom. The various kinds of food taken by animals affording milk, give to it various degrees of richness and different tastes: the milk of a cow which is fed upon the leaves and stalks of maize, or upon the refuse of beets, is very sweet, and that of a cow nourished with cabbages has not so sweet a taste, and exhales a disagreeable odor: the milk of cows which browse damp meadows is watery and insipid: from these facts we may establish as a principle, that the quality of milk may be so varied by the choice of food, as to adapt it to the wants of the individual to be nourished by it, whether he be a healthy man or an invalid.

The numerous experiments that have been made by Messrs. Deyena and Parmentier to ascertain the effect of food upon the milk of a cow, furnish the following results:

1st. That it is improper to change suddenly the kind of food, as it for a time diminishes the quantity of milk, even though the food be more succulent and of a better kind.

2nd. That all plants do not give to milk their characteristic qualities, and that there are some that do not exercise any particular action upon either of the constituent principles of milk.

By distilling milk in a water-bath there is obtained an extract of limpid liquor of about $\frac{1}{3}$ the weight of the milk employed, having the odor peculiar to milk, and containing a putrefiable animal substance which gradually renders the color of the extract cloudy, and its consistence viscid; this substance becomes putrescent in a longer or shorter time, according to the nature of the food upon which the animal affording the milk is nourished.

This first distillation does not change the nature of the constituent principles of milk: they remain in an oily mass of a sweetish taste, and a yellowish white color.

Butter and cheese are the two principal elements of which milk is composed: the cream which is separated from the milk, and from which a most profitable product is obtained, contains only one of them, butter, which is the most important part of the cream, and is obtained from it by a very simple process: the whey which remains after the butter and cheese have been separated from the cream, contains in solution some salts, and serves as a vehicle or dissolvent for all the constituent principles of milk.

The principles contained in milk are not united by a powerful affinity: when milk is allowed to remain at rest, the butter becomes disengaged and rises to the top, where it forms a layer in which it is found mixed with some milk;

it is this layer which is known under the name of cream. In this state the particles of butter have but a feeble cohesion, and still retain in combination a portion of milk which is by churning completely separated from them, when they appear with all their characteristic qualities.

As the preparation of these two products of the same fluid present different phenomena, I think it best to treat of them under different heads.

ARTICLE I.

Of Cream.

The surface of milk which is allowed to remain undisturbed in a cool place, becomes covered with a thick, unctuous substance of an agreeable taste, and usually of a yellowish white color; this substance is called cream. The first layer which is formed is not very close, but as the butter ascends, the coat increases in density; when it can, by pressing it with the finger, be removed without disturbing the milk, it is time for it to be skimmed off. Twenty-four hours, with a degree of temperature equal to 59° of Fahrenheit's thermometer, is sufficient for raising the cream: but at a higher temperature the cream forms more quickly, and has less consistency; it may then be removed in twelve hours. Cream is much better either to be used in that state, or for churning, than when it is allowed to remain a longer time upon the milk.

Cream should be kept in a cool place, and in jars with narrow openings closely covered, so as to exclude the air, and to keep it from being affected by the variations of temperature in the atmosphere.

From experiments recently made, we ascertain, that the larger the surface presented to the air by milk is, the more rapidly is the cream separated, and that a degree of heat equal to from 50° to 55° Fahrenheit, is the most favorable to this separation.

As the abundance and the quality of cream depend almost entirely upon that of the butter, which constitutes nearly the whole of it, I shall refer to the following article the remainder of what I have to say upon this subject.

ARTICLE II.

Of Butter.

I have already remarked, that there exists between the constituent principles of milk but a very feeble affinity: rest alone is sufficient to produce the separation of them in the course of a few hours, when the butter which exists in very minute particles in the milk, rises to the surface without any approach towards forming a solid body. In order to bring butter into a solid state, it is necessary to disengage from it all the other principles which it carries with it: this is done by means of churning.

It has been clearly proved that the quantity of butter produced from the milk of a new milch cow, is less than is yielded by the milk of the same cow five or six months after calving. It is likewise well known, that if cream be removed as fast as it is formed, the butter made from the first layers will be more delicate than that from the last. Milk that has remained a long time in the udder, furnishes more butter than that which is drawn as soon as it is secreted: thus milk that is drawn from a cow but once a day, will yield one seventh more of butter.

Milk obtained at the same milking presents similar differences; the portion which is drawn first, is thinner and more watery than the last drawn, and it yields less butter.

All these facts, ascertained by experiment, are capable of being extensively applied both in medicine and rural economy.

The particles of butter contained in cream, cannot be separated from the milky portions with equal ease, at all seasons of the year, or at all degrees of temperature; the operation of churning requires much more time in winter than in summer, nor can the process be shortened excepting by enveloping the churn in a hot cloth, or by plunging it into hot water; hot milk is sometimes added to the cream; but all these means affect more or less the good qualities of the butter.

During the heat of summer, it is necessary to set the cream in a cool place, and to churn at those hours of the day that are coolest; in some countries, it is customary to place the churn in very cold water.

The butter made in some countries, and which is thought to be of the best kind, is yellow, and, to deceive consumers, artificial means are had recourse to elsewhere, to give this product the same appearance. For this purpose the flowers of the marigold are put into stone pots, where they are allowed to macerate for several months, till a thick liquor is formed; this is strained through a cloth, and set by for use. Saffron flowers, roucou (annotto) boiled in water, the juice of yellow carrots, &c. are employed for the same purpose. Whatever coloring matter is made use of, it is put into the cream before churning, and in so small a quantity as not to influence, in any degree, the taste or wholesomeness of the butter.

The milk of all the various animals that has been subjected to experiment, contains the same principles; there is found no difference excepting in the proportion, consistency, and quality of the products.

The principles contained in milk are more easily separated in that of the cow, than in that of any other animal, and it is of this that the greatest use is made both for butter and cheese.

The milk of the sheep furnishes a large proportion of butter, but it never has the consistency of that from cows' milk; it is oily, and, unless very carefully washed, soon becomes rancid; it is more easily melted than the butter from cows' milk. It is difficult to curdle this milk; the caseous matter remains always in a viscous state; its taste is sweet and agreeable.

Goats' milk has more consistency than cows' milk; it is distinguished by a peculiar odor, especially at certain seasons: the cream which rises upon this milk is always very thick, and the butter made from it is uniformly white. It may be kept free from alteration a longer time than other milk: it is richer in caseous matter than any, excepting that of the sheep, but contains less butter than either cows' or sheep's milk. The slightly viscous character of the caseous matter, and its peculiar taste, render it excellent for making cheese.

There is no kind of milk, of which different examinations of the products afford such different results, as that of woman: not only does the milk of different individuals present very different results, but that of the same nurse, when analyzed at various times, offers unlike proportions of the principles: this has been ascertained by the experiments of Messrs. Deyeux and Parmentier. This milk, like any other, becomes covered with a coat of cream, but it is often the case, that the most prolonged churning cannot produce any butter from it. Repeated experiments have proved, that the caseous matter in this kind of milk increases with the lapse of time from the lying in; and that this is so feebly dissolved, as to become separated into very finely divided molecules at a temperature of 68° Fahrenheit: this substance has always some viscosity, and is never dry and quivering like that of cows' milk.

The astonishing differences which appear in woman's milk may be attributed to the passions of the mind, to nervous agitation, and to frequent changes of diet. The action of the two first agents is of the most powerful kind, and as they are exercised most vigorously and frequently upon the human species, it is not astonishing that they should exert a decided influence upon the milk of women. These observations deserve great attention from all who are interested in nursing children.

The milk of the ass bears a strong resemblance to that of woman; it throws up a cream which is neither thick nor abundant, and from which there may be extracted, though not without difficulty, a small quantity of soft, insipid, white butter, which easily becomes rancid.

Neither woman's nor asses' milk affords so much caseous matter as that of the cow or sheep; what is obtained is more viscous, and possesses but a slight degree of adherence to the *serum*. The resemblance of asses' milk to that of woman has caused it to be used in those cases, where it was necessary to employ a mild diet. It possesses the advantage over the last, of not varying so much in its quality and consequently in its effects.

The fluidity of mare's milk is less than of the two last-mentioned kinds, and its taste is less sweet: it furnishes some cream, but it is difficult to procure butter from it; it contains but little caseous matter, and in all its products bears a resemblance to the milk of the human female and of the ass.

From the foregoing statement we perceive that the ruminating animals afford similar kinds of milk, and that this milk possesses peculiar and distinguishing characteristics: all the kinds contain the same principles, but these principles vary in proportion, quantity, consistency, and taste.

The difference existing amongst the several kinds of milk greatly influences the products obtained from them; but if they be rightly mixed together, the qualities of one kind may serve to correct the faults of another, and thus more valuable products may be procured from the combination of two or more kinds than could be had from either separately.

The process of churning unites into one mass all the particles held in solution by milk, and brought into a somewhat more condensed state in cream; but there still exist in butter some milky particles, which cause it to undergo a change: to avoid this, it is necessary to free the butter carefully from milk. When butter is made from fresh cream, and is to be immediately consumed, nothing more is done to it than to work it over carefully with the hand, till all the milk is expressed from it, it then retains all the sweet and agreeable flavor of cream: but when it is to be kept for any length of time, it is necessary that it should be kneaded with cold water, till the liquid runs off free from milkiness.

All the operations required to bring cream into completely-made butter, should succeed each other without delay; for the milk expressed from butter made of cream which has remained too long a time upon milk, or in the churn, has a vinous taste.

The less care there is taken to free butter from the buttermilk, the sooner will it become rancid; in order therefore to preserve to it all the qualities of fresh butter, it should be carefully washed and kneaded: it must likewise be kept in a cool place, or under cold water that can be frequently changed: it is sometimes melted at a low temperature, and allowed to remain in this state till all the watery particles contained in it are evaporated. I have, in a former place, spoken of the method of salting butter; this is the surest means of preserving it. (See Chap. X.)

According to the experiments of Messrs. Deyeux and Parmentier, the rancidity of butter arises from its combining with oxygen when exposed in contact with the air: butter absorbs about $\frac{1}{4}$ of its volume of oxygen, and acquires from the union a strong, acrid, disagreeable taste.

ARTICLE III.

Of Caseous Matter.

When milk has been skimmed, if it be afterwards heated to any degree short of ebullition, there form upon the surface pellicles which gradually acquire some degree of consistency, and which may be easily removed: by continuing the heat these may be renewed, till at length the milk can furnish no more of them: in this state milk can be boiled without occasioning any of that violent swelling and rising which is so hard to check, and which causes the boiling of this liquid to be so troublesome; but then it will contain neither butter nor caseous matter: the butter has been separated in removing the cream, and the pellicles are the caseous matter: what remains after these two operations is only whey, holding in solution some known salts.

I have already remarked, that these pellicles form only in contact with the air; they do not appear when milk is boiled in closely-corked bottles: the production of them may be accelerated by the passage of a current of air over the surface of the milk.

The caseous matter may be separated from skimmed milk by exposing it to a gentle heat, when it assumes the form of a soft, quivering mass; this is called curd: two or three days' exposure to a heat of from 68° to 77° Fahrenheit is sufficient to produce this effect.

As the caseous matter adheres but slightly to the serum, and to the salts which are contained in it, it can be separated by means of a great variety of different bodies: it is to the action of some one of these that recourse is had for coagulating milk.

Acids of all kinds coagulate skimmed milk very quickly; the change takes place more or less rapidly according to the strength of the acid employed; if a larger quantity be used, the curd is injured by retaining the taste of the acid.

The salts which contain an excess of acid, as the cream of tartar, and the salts of sorrel, produce the same effects, but the coagulation is not complete unless the milk is near boiling when the salts are thrown into it.

The rapidity with which the sulphates coagulate milk is very remarkable: the action of these is most energetic upon boiling milk.

Alcohol speedily precipitates the caseous matter under the form of fine molecules, at the bottom of the vessel.

Very acid plants and the flowers of some vegetables, such as the artichoke and the thistle, curdle milk : these are usually employed by infusing them in cold water, and their action upon warm milk is very powerful.

The substance however which is most generally used is a portion of the milk curd which is found in the stomachs of young calves that have been killed before they were weaned. The use which is made of this substance has given it the name of *rennet.** This substance is prepared for use in the following manner. The membrane of the stomach of a young and newly killed animal is opened, and the coagulated milk is taken out, washed with cold water, dried with a linen cloth, salted, and returned into the membrane ; this is suspended in a dry place that the rennet may be freed from moisture : the rennet may afterwards be used by mixing a little of it in milk, and then throwing the liquid into the milk which is to be curdled.

The quantity of rennet necessary to be employed at any one time for the same measure of milk, varies very much according to the quality of the milk and the temperature of the atmosphere : thick, rich milk, which has not been skimmed, requires more than that which is thin, or from which the cream has been removed. In winter it is often necessary to warm milk slightly to make it curdle.

As soon as the milk curdles it is allowed to remain undisturbed in a cool place, in order that the curd may acquire some degree of firmness, and that all the particles may become united in one mass, and likewise to allow all the whey to drain off: it is then dipped up with a skimmer and put into a vat or bucket of osier, through which the whey contained in the curd can escape freely. As soon as the curd has acquired a certain degree of consistency in the willow baskets, it is removed into vats of earthenware having small holes in the bottom ; through these the whey still continues to drop, and the curd gradually increases in density. Curd, from its first formation to the period of which we are now speaking, forms an article of diet equally healthy and agreeable, and furnishes a great

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[* In this country the term is applied to the dried and salted stomach of the calf, a piece of which is employed to produce the coagulation required.—Tr.]

resource for variety in the food of the inhabitants of the country. But as these preparations cannot be preserved for any length of time, it is necessary to find some means of keeping them free from alteration, or so to moderate and govern decomposition, that the food furnished by the caseous matter may be varied, and the power of keeping it prolonged: this object is obtained in the fabrication of cheese.

The existence of whey in curd hastens most powerfully the action of putrid decomposition; and, in order to prevent or retard this change, it is necessary that the whey be forced out by mechanical power. Those cheeses which are the best dried, may be preserved the longest time: in order to hasten the drying, the curd is carefully kneaded, and in some cases the cheese is exposed to heat or to a strong pressure.

The period during which cheeses can be kept may be prolonged, by impregnating them well with salt; this is done in the following manner: when the curd has acquired the requisite degree of consistency, the surface of it is furrowed and covered with pounded salt; the next day the cheese is turned, and the same operation performed upon the other side of it. This salting is repeated till every part of the cheese is well seasoned, it is then placed upon a bed of straw, and turned from time to time. The straw upon which cheeses are placed, must be frequently changed, and the planks washed, and in every part of a dairy the greatest cleanliness and neatness should be observed.

The surface of a new cheese gradually loses its white appearance under the above treatment; the size is diminished, and there is formed an external crust harder than the middle, and having a sharper and less agreeable taste.

When the caseous matter is precipitated from milk retaining its cream, the cheeses formed from it are not so dry as those which consist entirely of the caseous part; their taste is mild and their substance more mellow and unctuous.

Independently of the modifications which cheese is susceptible of, from the addition or suppression of cream, the mixture of different kinds of milk varies it greatly. I formerly remarked that the milk of the sheep and goat was softer and more viscous than that of the cow; this renders the cheese made from it mellow, besides its possessing a very agreeable flavor. The most celebrated cheeses are made from a mixture of cows' milk with the milk of sheep or goats.

I will here give a hasty sketch of the most usual processes by which cheese is made.

When the curd has been deprived of its whey, excepting what may ooze from it in the vats or upon the straw, it undergoes various degrees of decomposition, which at different periods furnish several kinds of food.

A new or white cheese gradually shrinks, and its surface becomes covered with a crust or rind, whilst the interior preserves more of its softness: at the end of some time fermentation takes place, when it exhales an odor which becomes more and more sharp; a similar change likewise takes place in the taste: this stage of decomposition is the most favorable for disposing of white cheese.

When cows' milk that has been skimmed is used for cheese, the article produced from it is always dry; but if the curd be formed from milk retaining the cream, the curd contains, in addition to the caseous matter, all the principles of the cream; and, when treated in the usual manner, a white cheese is obtained from it which is not slow in changing its consistence: the interior of such a cheese softens and takes the form and nearly all the character of cream. Cheese in this state is delicious to the palate; but it soon undergoes a putrid decomposition which changes its quality.

There is a very delicate and much sought for preparation, which is improperly called cheese; this is made by churning fresh cream till it has acquired a degree of consistency, without the butter's being separated from it.

All kinds of cheese cannot be kept good a long time; but if the curd be strongly pressed so as to extract all the whey, and afterwards carefully salted, cheeses may be made of it which can be preserved a considerable length of time. To effect this, the curd is divided with a wooden knife, kneaded, and squeezed with the hands; and when all parts of it have been well worked, it is put to drain. As soon as the whey has ceased to drop from it, it is again kneaded and submitted to a considerable pressure, by which all the liquid particles which can be extracted from it, are forced out.

When the curd has by these operations been brought to a due degree of dryness, it is salted: this is done by again carefully kneading the curd and afterwards breaking it into pieces, into each of which the salt is worked by the hand; a mould or form is then filled with the curd; this is covered over with a cloth, upon which is placed a weight to press the cheese; by this process the salt is made to penetrate the whole mass, and the last remaining portions of whey are forced out.

The whey which is disengaged by this last operation is very salt, and is usually preserved to moisten cheeses with, when by their progress of decomposition they have become too dry.

The curd remains under the press several days, and is turned from time to time, that the salt may become incorporated with the mass, and that the whey may be perfectly separated from it.

When the cheese is taken from the press it is placed in a situation where the temperature is cool and equal, and where it will not be exposed to light or insects, and there it undergoes the other processes, by which the making of a cheese is completed. These processes vary much in different places: in some a cheese is turned every day, and its surface, as soon as it becomes dry, is moistened with salted whey: if a cheese becomes mouldy, the rind is forcibly scraped with a wooden knife; in other places the rind is scraped and taken off every five or six days, and by this means the part that is most advanced in decomposition, is removed and sold at a low price to the people. As soon as this crust is taken off, the new surface is rubbed with salt, which is forced into it with the hand; the cheese is then carried into the cellar: the operation is repeated till the cheese is disposed of.

If, in drying the curd, the action of fire is added to compression, a firmer, harder cheese, and one of very different qualities, is obtained: a cheese prepared in this way can be kept a longer time than others.

In the manufacture of this kind of cheese, the milk is placed in a boiler over a moderate fire, and the necessary quantity of rennet is stirred carefully into it: as soon as the rennet begins to affect the milk, it is removed from the fire, when the curd very soon acquires some degree of solidity: all the whey which can in this state be extracted from it, is removed, and the boiler again placed upon the fire: the curd is constantly stirred either by the hand or with a slip of wood: this operation is continued, till the clots which swim in the whey, which is expressed from them, have acquired so much firmness, as to resist the pressure of the finger, and present a yellow appearance: the boiler is now taken from the fire, and the stirring and squeezing continued, till the curd is cool, when it is put into a mould and submitted to a strong pressure to extract all the remaining serum.

After these first operations are completed, the curd is again kneaded, in order to give it the different forms under which this kind of cheese is known in commerce. The cheeses when formed, are rubbed over with salt; this is repeated every day, and the cheeses are at the same time turned; the salting is completed when the surfaces exhibit a superabundance of moisture, as this announces the cheeses to be saturated with salt. The cheeses are then put into a cool place, where they will be safe from insects.

In general, cheeses made in this way are hard and dry, and may be kept a long time: the nature of the caseous matter of cow's milk, from which they are prepared, contributes not a little to these qualities.

There is no food made use of by man which presents so great a variety as does cheese; this arises from some circumstances of which we can ascertain the causes.

The milk which is furnished by animals of different kinds, is not of the same quality, and consequently the butter and caseous matter obtained from it are very dissimilar, and the cheese made from sheeps' or goats' milk is much more mellow and agreeable than that from cows' milk.

The milk of animals of the same kind varies very much with the health, the food, season of the year, length of time from bringing forth young, &c.; all these circumstances modify the quality of this secretion indefinitely.

The mixture of milk obtained at different times, during a space of several days, the quality and proportion of the rennet employed, the temperature of the weather, and the calm or stormy state of the atmosphere, the cleanliness of the dairy, and of the utensils employed, the degree of care with which the curd is freed from whey, the choice of a proper kind of salt for seasoning, the course which is pursued in governing the fermentation, and the size of the cheese upon which all these circumstances operate, combine to influence the quality of the product; and however much care may be taken in the various parts of the process of cheese-making, it is very difficult always to obtain the same results: it is for this reason that we seldom have two cheeses precisely alike in all respects.

The custom which is practised in some countries, of skimming the milk before forming the curd, gives to the product a peculiar character; such cheeses are dry and very suitable for keeping; they may be made of very great size.

By mixing the milk of the goat or sheep, with that of the cow, cheeses may be made very superior to those obtained from cows' milk alone: it is from this mixture that the two best kinds of French cheese, the Roquefort and the Sassenage, are made: if the first of these is superior to the last, it is, I think, owing to the cellars in which it is prepared: these cellars are backed by a rock which presents numerous chinks and openings, by which there constantly escapes a rapid current of air, which keeps the temperature but 4° or 5° Fahrenheit above freezing; * the fermentation, therefore, is very slow, and may be regulated at pleasure.

Cheeses made entirely of goats' milk are more delicate than those made partly of cows' milk, but they cannot easily be kept for any length of time; they should therefore be made small, and be eaten as soon as they have attained their perfection.

Much cheese is made in France, but, with the exception of five or six places, but little care is given to this article, and the consumption of it is confined to the vicinity in which it is fabricated. None of our cheeses are capable of being kept any great length of time.

The importation of foreign cheese is very considerable: it is desirable that extensive establishments should be formed, where the product from the neighboring dairy farms should be brought to undergo the necessary manipulations.

The manufactories of Roquefort are supplied in this manner with new cheeses bought upon the mountains of Larzac.

The successful attempts which have been made in many parts of France, to imitate the cheeses of Holland, Switzerland, and England, leave no doubt in regard to the possibility of introducing this valuable branch of rural industry among us.

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* In the month of July, 1784, my thermometer indicated 22° (72° Fahr.) in the external air: when carried into these cellars, it sunk to 2° (36° Fahr.), and there remained.

CHAPTER XII.

COMPARISON BETWEEN AN AGRICULTURAL AND A MANUFACTURING NATION.

No nation in Europe can be called purely agricultural or purely manufacturing; in all, these characters are more or less united.

But when a nation has formed within itself centres of manufacturing industry, the products of which are everywhere diffused, and when the existence of a large portion of its inhabitants essentially depends upon the prosperity of its manufacturing establishments, it is justly styled a *manufacturing nation;* whilst the nation which exports a large proportion of the products of its soil, and has only a few manufactures to supply its most urgent local wants, is an *agricultural nation.*

Several causes conspire in establishing this distinction.

A nation which possesses an extensive and fertile soil, capable of furnishing occupation to its whole population, cannot but be agricultural; but if its population exceed the demands of agriculture, there must necessarily be either an emigration of a part of it to other countries, as has been frequently observed in the north, or a formation of manufacturing establishments to provide them with employment.

Whenever, by the revolutions which have so frequently taken place in Europe, a part of the population has been forced to migrate into desert countries, of an almost barren soil, these colonies have in the first place drawn from the soil, by labor, all that it was able to furnish, and manufacturing industry has then become a powerful auxiliary to agriculture, in ensuring them a subsistence. The population of mountainous countries everywhere affords examples in support of these principles.

We shall even observe that in those mountainous countries, where the frugality of the inhabitants makes labor cheap, manufacturing industry has maintained itself and prospered, until machinery has superseded manual labor, and made it an insufficient auxiliary in the execution of products.

Manufactures have then established themselves wherever science and the mechanic arts have made the greatest progress, and France and England have divided this branch of industry between them.

France was already in possession, almost without a rival, of manufactures of silks, lawns, cambrics, laces, fine cloths, and several other articles essentially connected with its agriculture; but England, toward the middle of the last century, opened a branch of industry in the cultivation of which she has enjoyed a high superiority till the present day,—that of the spinning and weaving of cotton; and, since that period, she has carried to a remarkable degree of perfection all other kinds of manufactures.

France has constantly shown herself superior in the application of chymistry to the arts; England in the construction and employment of machinery.

The application of the sciences to manufacturing operations has rendered labor more regular, more prompt, more economical; the fabrication of products has been no longer limited, and their consumption has increased, in consequence of their superior quality and low price.

But has this great revolution, effected in manufacturing industry, been advantageous to the human race? It has unquestionably been so to the undertaker, and to the consumer; but has it also been so to agriculture?

Formerly, almost all the manufactured articles necessary to the inhabitants of the country, were made in every country household, and whatever was not needed for domestic use, was advantageously sold; to this labor were devoted the long winter evenings, and all the time not required for the cultivation of the soil. The low price to which the use of machinery has reduced these articles no longer permits the farmer to sustain a competition in price, and he finds himself deprived of a resource which was of itself sufficient to pay his taxes: thus agriculture is a sufferer.

These large manufacturing centres have attracted the inhabitants of the country by the offer of higher wages; but hardly has he entered the establishment, when a total change takes place in him; he is no longer the frugal peasant; in changing labor, diet, and society, he gradually contracts new habits; his health is affected, and the human race is insensibly deteriorated. Should a stagnation of commerce take place, he is thrown out of employment, and has then no resource but in public compassion.

These inconveniences are carried to excess in England, where the vicissitudes of commerce often peril the existence of half the population, and cause disorder in society.

More happy than England, France cannot be tormented by these fears. In a population of from thirty to thirty-two millions, the proportion of those possessing no property, is hardly one sixth, and the resources which agriculture presents are immense. France possesses but two great manufacturing centres, Lyons and Rouen; and when the operatives there are out of employment, they disperse themselves in the country, where they find occupation.

Manufacturing and commercial crises are less numerous in France than in England, and there are two principal reasons of this difference: the first is, that manufacturing is carried on to a much greater extent in England than in France; the second is, that the principal markets for the products of English labor are abroad, while France possesses thirty-two millions of consumers at home.

This last advantage in favor of France is immense, because nothing can deprive her of it, and because it could only be compensated for by the opening of numerous markets abroad. In England, agriculture holds a second place; in France, it takes the precedence over manufactures.

The crises to which agriculture is liable, are less frequent than those of manufactures, and are not attended with the same consequences; periods of scarcity are never so terrible in the country as in cities; the farmer always husbands resources for these calamitous times, and his subsistence is never made uncertain.

The labors of agriculture maintain a frugal, healthy, and hardy population; those of manufactories often alter the most robust health, and dissoluteness of all kinds is almost always an appendage of the manufacturing laborer.

There is, then, no doubt, that, in many respects, agricultural is preferable to manufacturing life.

But, on the other hand, the fortunes made in agriculture are slowly and laboriously acquired: such a competition in price exists as to the products of the soil, that the profits of the proprietor are necessarily very limited; and although agriculture offers an honorable and certain subsistence, and one presenting fewer chances of a reverse, yet the greater number rush to manufactures, as promising more rapid gains.

Governments, however, almost universally favor manufactures rather than agriculture. This predilection would seem to be suggested to them by the example of England, who, by means of her manufactures, has reached, in a short time, the highest degree of prosperity.

Agriculture has yet this advantage over manufactures, that almost all its products are of the first necessity, and that the changes of taste, and the caprices of fashion, have not the same influence upon it, as upon the products of manufacturing industry: a nation rich in its soil does not experience those fluctuations to which a manufacturing nation is exposed by the mere progress of foreign manufactures.

In all these respects, the prosperity of France rests upon solid bases; its soil is adapted to all kinds of culture, and possesses several peculiar to itself; the excellence and variety of its wines, in particular, find consumers everywhere, and this branch of cultivation alone produces at the present day more than a thousand millions.

We are not, then, to be surprised if France have always risen, as by a miracle, from every crisis which she has experienced, and may conclude, that if she had been wisely governed, she would long since have stood first among nations.

CHAPTER XIII.

OF LARGE AND SMALL ESTATES.

The question as to large and small estates has for some years occupied all minds in France. Some would unite all property in the hands of a few families; others are willing to leave it to time and private interest to effect a suitable division, and one advantageous to the nation and the government.*

Large landed estates spring from the first institutions of monarchy; privileges, grants, and the division of inhabitants into classes, centre all property in the hands of a few; the rest of the population, condemned to servitude, is attached to the soil.

Gradually the serfs are freed; property is divided; but the new proprietors have been able to acquire and to possess only on burdensome conditions; their lands have

* See the excellent Memoir of the Vicomte de Morel Vindé on this subject.

been loaded with rents and imposts from which the first possessors were exempt, and thus two kinds of property are established.

While this state of things has continued, agriculture has made no progress; one class was too rich to perceive the necessity of improving their estates, the other was too poor to attempt it.

When the power of acquiring property has been given to all, and particularly when the law has equally protected all proprietors, and abolished all privileges attached to the soil, or to individuals, the result has been a division of property, and an advance in agriculture.

The revolution has had two results advantageous to land-owners; the first, that of effacing the last traces of inequality in property; the second, that of offering to the agriculturist an enormous quantity of lands, which he could purchase at a low price.

The natural consequence of this state of things has been to increase the number of landed proprietors, and the respectability of the farmer.

Is the division of the soil into small estates an advantage or an evil? That is the question which we are to examine.

Large estates have the advantage of affording scope for all the developements of agricultural industry. That which forms the basis of subsistence, and a large proportion of the raw material of manufactures, is here united in one grand scene of operation. The productions of a large domain not only suffice for the subsistence and support of the proprietor and his agents, but the surplus supplies the wants of all, and fills the public markets.

Add to this, that large proprietors are more enlightened than small ones, and, especially, better enabled, by their more ample fortunes, to attempt improvements.

There is, then, no doubt that large proprietors are desirable in France; but are we therefore to be alarmed at the increase of small farms? I think not.

If, as I have already said, large estates have been the necessary result of our ancient institutions, the division of landed property is the natural effect of those by which we are at present governed. The suppression of the right of primogeniture, and of all the burdens which weighed unequally upon different classes of proprietors, and the prosperity which has prevailed among the inhabitants of the country, have necessarily increased the number of land-owners; but will this increase be unlimited? No; it will stop when the advantage of extensive agricultural operations is more fully realized, and when the produce of the soil can no longer liberally pay the labor of which it is the object.

To elucidate this question, let us see what has taken place hitherto.

In districts devoted to the greater crops, the division of land has had no sensible effect; everywhere we find the same extent of agricultural improvement, and the supplies of cattle, corn, fodder, and wood for the market have suffered in no way.

In a very large number of communities, of which almost the whole territory belonged either to the nobles or to the clergy, those of the inhabitants who were already proprietors have bought as much as suited their convenience, and those who were not proprietors have become so.

But it is particularly in districts devoted to the lesser crops, that the division of property takes place: there, almost all the labor is manual. The culture of the vine, and that of the different kinds of pulse, require particular care and intelligent superintendence. To this the small proprietor consecrates all his time; he labors at the best times and the most favorable seasons; he employs the rest of his time in laboring for the public.

Let us now observe the results of the division of the soil into small estates.

These results may be considered with reference to three points: the interest of agriculture, the welfare of the state, and public morality.

1. *The interest of agriculture.*

When a large proprietor directs his information and his wealth to agricultural improvements, this is without doubt advantageous to agriculture: but these examples are rare. The cultivation of a large domain is usually entrusted to farmers, who follow step by step the received methods, and do not venture to adopt useful changes, because the shortness of their leases does not permit them to hope to reap the benefits of them. It is rare, too, that in a very extensive tillage, there is enough of hands, of manure, and of working cattle, to carry cultivation to its perfection.

It cannot be denied that the first interest of agriculture is to produce the greatest possible amount upon a limited extent of soil, and to furnish produce at the lowest price to the consumer: now, in this case, all the advantage is in favor of the small proprietor; he cultivates the soil himself, and brings to his labor all the interest of a proprietor; he labors only at the most favorable times, and gives his unoccupied time, for wages, to the work of others: the large proprietor is not at liberty to be thus guided by his convenience; he is hurried along and commanded by time and labor.

The small proprietor leaves no part of his ground unoccupied; he cultivates steep banks with pulse; plants potatoes in any vacant space in his vineyard: the large proprietor neglects all these details.

2. *The welfare of the state.*

It is generally admitted, that the large domains, which have been divided in consequence of the revolution, produce much more than they did; that uncultivated lands, especially in the south, are now covered with noble vineyards; that prosperity has prevailed in the country from the increase of the number of proprietors.

These undeniable facts have produced important advantages; the increase of produce has furnished means for the subsistence of a more numerous population. Wealth, introduced among the inhabitants of the country, has enabled them to maintain their children, and give them a better education; the consumption of produce of all kinds has increased, and agriculture and manufactures have found larger markets for their products.

So long as twelve years ago (I write in 1826), the amount of taxable quotas in the land-tax was ten millions four hundred and fourteen thousand one hundred and twenty-one, according to the last lists furnished by the Duke de Gaëta. The taxable quotas under 500 francs amounted to nine millions nine hundred and fifteen thousand. Since that time the number of quotas has increased, and particularly the smaller ones. And never has the land-tax been more regularly paid.

Another advantage resulting to the state from the division of property, has been that of rendering changes more frequent, a natural result of the increased number of proprietors: these changes, as they become more numerous, bring much more money into the treasury.

According to the very exact verification made for five years by the department of indirect taxation, there were produced on an average, at the commencement of the century, thirty-five millions and six hundred thousand hectolitres* of wine: this amount has remarkably increased since that time, not only because the vine has continued to be planted, but because the culture of it has been improved: the case is almost the same as to all the produce of the soil. It cannot be denied that this increase of production is the result of the division of the soil into small farms. I have been for some time the proprietor of a pretty extensive vineyard, which I carefully cultivate, and I have constantly observed, that the small proprietors who worked for me raised at least double from an equal extent of land belonging to them; my produce, in truth, was of a little superior quality; but, at the market price, the quantity more than compensated for this difference in quality.

3. *Public morality.*

But it is particularly as it respects public morals that the increase of the number of small proprietors is advantageous. To be convinced of this, we need only compare the condition of the man possessing no property, with that of the possessor of property, however limited in extent.

The laborer without property is retained only by habit in the place of his birth; his two hands are his only property, and he places them at the disposal of him who pays best; he is entirely dependent upon the work he finds about him, and when employment fails, he changes without regret his place of abode, to seek it elsewhere. The institutions of his country are indifferent to him, because he takes no part in public affairs; he feels no interest in the preservation of order, because a state of disorder presents to him more favorable opportunities. Almost always discontented with his situation, he becomes restless, jealous, miserable; he accuses God and man, and seeks every opportunity which offers of rendering it better. Troubles, insurrections, robberies, assassinations are frequent wherever there are many laborers without property and few proprietors; and governments are forced to establish enormous *poor-rates*, as in England, or to supply the poor with food at the gates of convents or chateaux, as in Spain.

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* See note, page 131.

The subsistence of the laborer without property is never certain; the frequent diminution or suspension of labor in manufacturing establishments reduces him to misery, and promotes the developement of all the vices which result from it; the labors of the country vary with times and seasons, and do not offer constant employment to one not attached to the farm. His lot is then always variable and precarious.

The man without property who is single, commonly leads a dissolute and intemperate life; he who would have a family commonly becomes more unhappy; he cannot give his children a suitable education, and they soon contract all the vices of a depraved society.

The condition of the small proprietor is very different from this; he is rooted to the soil, and thence derives all the advantages of his situation. He works on his own land in his leisure moments, and devotes the rest of his time to earning wages on the estates of others. This double source of profit abundantly secures his existence and that of his family. His children and his wife coöperate in the culture of his little farm; idleness is banished from their household, and good morals, which are always the result of a laborious life, prevail there.

The small proprietor is interested in the maintenance of public order, because he would be a loser by trouble and disorder; he loves the institutions and the government which protect his property; he regards the welfare of others, because he would have others regard his own. His interest, his affections, his fears, his hopes, are concentrated and repose in that little spot of earth whose safety and prosperity are his only wish. He has in truth a country, whilst the other is a true cosmopolite, a stranger to all social interest.

Some appear to be alarmed at the increase of population attendant upon small proprietorship; but this increase of population is a certain sign of an increase of the means of subsistence and of the wealth of the inhabitants, whilst the diminution of population announces public misery.

In proportion as the population of the country increases, manual labor becomes more abundant, and produce increases in quantity and is reduced in price.

Thus, stripping the question of all that is connected with certain political considerations, the division of landed property is an advantage to agriculture, to the state, to public morals.

Men who take their opinion only from the past, would bring back property to its former state; but times are not the same, and a return to the ancient order of things is impossible. The division of property will continue to take place, so long as the small proprietor shall obtain more produce from a given extent of land than the large one, and so long as large owners shall divide their lands into small lots, to obtain a more advantageous sale of them: it is evident that a different result could be obtained only by reducing the destitute laborer to a degree of misery which would not permit him to economize with a view to acquiring property, or by prohibiting sales of land in small portions; now, the first of these means is contrary to justice and good morals, and the second to the rights of property.

When, in the session of 1825, the government proposed to reëstablish the right of primogeniture, it had neither paid regard to the changes which had taken place since the revolution, nor to the respective rights of the different members of the same family. Formerly, almost all the large estates belonged to the most ancient families in the kingdom; they passed, undivided, into the hands of the eldest son, because the army, the clergy, or the order of Malta afforded rich endowments for younger sons, and convents offered great resources for daughters; but, at the present day, what would become of younger sons if the right of primogeniture were reëstablished? Deprived of the expedients offered by the old state of things, incapable of laboring upon the soil, they would live at the mercy of the head of their family. It is then particularly to old families, which, notwithstanding, it is meant to benefit, that the reëstablishment of the right of primogeniture would be fatal.

Let us but leave it to time and to private interest, and the division of property will not pass the bounds prescribed to it by these supreme regulators of all things.

The division of estates will continue to take place, 1. in the vicinity of cities, where, from the constant attention bestowed on the soil, from the abundance of manure, the facility of transportation, the proximity of the market, and the certainty of a safe and advantageous sale, immense crops of vegetables and fruits of all kinds and of every season may be obtained by manual labor; 2. in vine countries, where the cultivation requires constant labor, and where the production is always proportional to the care bestowed upon the land; 3. in uneven lands, like valleys, mountains, &c. where cultivation is confined within narrow limits, and where the lands capable of it are separated by a barren soil.

In all these cases, the plough and working-cattle cannot be employed in labor; every thing is done by manual labor, and at most, the owner of each estate possesses a few cows and goats, and sometimes a few sheep, to secure subsistence, and increase the comfort of his household. We often find a numerous population assembled in those wild places where the soil seems to refuse any cultivation, and where the inhabitant, temperate and hardy, obtains, by industrious labor, crops which satisfy his wants and supply the neighboring markets. Those numerous countries, which are not capable of high cultivation, would be deserted without the assistance of the small proprietor; and it may be said, to his credit, that he creates produce in places which nature had devoted to the most complete sterility.

We nowhere see small proprietorships existing in places favorable to high cultivation. The vast domains of Beauce, Brie, Soissonnais, Upper Languedoc, exist undivided, and are always the granaries of France; the rich pasture lands of Normandy, Poitou, Anjou, &c. always maintain the same number of cattle; our large forests have remained untouched; population and the means of living have considerably increased; our markets are abundantly supplied; wealth has spread through the country; manufactures have made immense progress; taxes are paid regularly and without compulsion.

Let us beware of disturbing, by laws or regulations relative to property, this general harmony and public prosperity, which secure the happiness and prosperity of our country.

CHAPTER XIV.

THE ENCOURAGEMENT WHICH OUGHT TO BE GIVEN BY THE GOVERNMENT TO FRENCH AGRICULTURE.

The very limited degree of information which, even to the present day, has been diffused in the country, and the almost abject part which the cultivator of the soil has been made to play, have arrested the progress of agriculture there: faulty methods of cultivation have been retained, and France has been far outstripped by other nations in this noble career of public prosperity.

Now that our institutions have replaced the most useful class of men in the first rank in society, it is to be hoped that the agriculturist will feel all his dignity, that he will love his condition, and that, by labor and instruction, he will create resources hitherto unknown to him. But this useful revolution requires the support of government: lands are too much divided, the fortunes of proprietors are too limited, to allow the expectation of seeing great examples and useful lessons given without public assistance.

In France, the most frivolous arts are almost everywhere provided, at the cost of government, with the facilities for practical instruction; and agriculture alone is destitute of a public establishment, where the principles and practice of this beautiful science may be taught. The need of communicating instruction through the country is so generally felt, that we see, in every department, educated agriculturists associated for the purpose of communicating their observations, of discussing new processes, and of proposing the improvements of which agriculture is susceptible.

These associations are useful; they render important services; but they have not the advantage of forming young agriculturists, nor of making them acquainted with the true principles of the science. We need, for this object, special instruction and men who shall be exclusively devoted to it.

In England, where rural fortunes are divided among from twenty-two to twenty-five thousand families, wealthy proprietors establish prizes, of which they make a formal distribution every year. They assemble within their domains, upon a fixed day, a considerable number of agriculturists, each one of whom produces for examination and decision the finest products of his cultivation. These festivals, instituted for the promotion of agriculture, excite the most active emulation and produce the happiest effects.

It has been in vain attempted, in France, to imitate England; fortunes are here too limited to enable individuals to meet expenses so considerable. Government alone can and ought to furnish such institutions.

It would be necessary that at least two experimental schools of agricultural instruction should be established in France, one in the south, and the other in the north, in order to embrace all kinds and varieties of culture which belong to our soil and our climate.

The extent of land devoted to each establishment should be about two hundred *hectares*,* and the buildings should be able to lodge at least one hundred pupils.

The nature of the soil must be sufficiently varied to admit of all the different kinds of culture adapted to the climate.

There would be required in each establishment a director, entrusted with the care and management of it, and two professors, one of Chymistry applied to Agriculture, the other of Veterinary Medicine.

The purchase of lands and the cost of the establishment might be estimated at from a million to twelve hundred thousand francs; but the money paid for board and the profits of cultivation would at least cover all the annual expenses.

It would be useful to connect with each establishment a workshop, for the manufacture of all implements of husbandry, perfected or newly invented, or employed in rural operations. The profits of the workshop would form a considerable revenue for the establishment.

The young people admitted into the establishment as boarders should be employed in all agricultural labors; they should be instructed in the responsible management of an estate.

There should annually be a formal distribution of prizes to those pupils who have distinguished themselves by good conduct, and to those who have made the greatest progress.

A royal ordinance should establish these principles, and

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* The *hectare* is equal to 2 acres, 1 rood, 35.4 perches.

the Minister of the Interior should make the rules necessary for securing their execution in every particular.

I have no doubt that these two establishments would produce, in a few years, the best effects upon French agriculture. The pupils who left these schools would diffuse everywhere instruction and good methods of cultivation, and the first of arts would no longer depend for preservation on a mere routine, which perpetuates errors and prejudices.

In establishing these two schools, the government will have fulfilled only one part of its duties to agriculture; it owes it roads and canals to facilitate the transportation of commodities; it owes it a wise regulation of taxes, so that they may never represent a single part only of the benefit derived from agricultural operations; it owes it a kind and paternal administration; it owes it assistance when *accidental casualties* or *diseases* have ravaged crops and destroyed cattle.

And even in this, the government has not yet fulfilled all its duties to agriculture, to their full extent; it should excite emulation, which, in the arts, works miracles, and should reward agriculturists who make important discoveries, and those who improve or extend useful methods of cultivation.

These pecuniary encouragements should not be distributed at random, nor badly bestowed, for they would then extinguish emulation in place of rousing it.

A well-selected jury should designate, every year, to the authorities, those cultivators of the department who have deserved best of agriculture; and the distribution of prizes should be made in a public and solemn sitting.

The object of the examinations of the jury should be to determine who are those agriculturists who have introduced upon their estates animals more valuable and more useful than those of the country, and those who have improved the native breeds;

Those who have established the system of cropping most favorable to the soil;

Those who have discovered modes of manuring and improving the soil, before unknown or not used;

Those who have planted the largest number of trees;

Those who have opened to culture lands hitherto barren;

Those who have introduced the cultivation of plants, the produce of which is more profitable than that of those usually raised;

Those who have invented or improved agricultural implements;

In a word, all those who should have rendered services in any department of agriculture, would be entitled to these rewards.

I believe that prizes to the amount of ten or twelve thousand francs, annually distributed in each of the principal departments, would be sufficient to excite a happy emulation among agriculturists.

The government should also reserve to itself some places in the two practical schools of agriculture, and there place the children of the most distinguished cultivators, to be maintained at its expense.

But it is not enough to create agricultural products; channels must be opened to them, and a market secured; and thus the government has other duties to fulfil. Whatever facilitates transportation will become of general utility, by increasing the consumption of commodities, and lowering their price; the first object of attention is then the means of attaining this end.

To arrive at a conclusion respecting these means, we must first state the present condition of things.

There are some roads, which may be called *parish roads*, which merely form a communication between the estates of one parish; these consequently are merely roads for farming operations.

There are others, which form a communication between adjacent parishes, and which may be called *district roads*.

There are also others, which connect together all the towns of a department, which may be called *departmental roads*.

And finally, the *great roads*, which form communications between all the departments.

The care of maintaining parish or farm roads is entrusted to the local authorities, and one needs only a hasty journey through France, to be convinced of the neglect and carelessness with which these communications are treated. Transportation on these roads is difficult and tedious; twice the number of animals are employed upon them which would be necessary if the roads were kept in a proper state, and the price of commodities is increased by the difficulty of transportation; all this is detrimental to the proprietor, who indeed admits it, but no one is willing, at his own expense, to make repairs by which all would be benefited, and the evil continues.

To obviate these inconveniences, it would be necessary that each municipal council should prepare a statement of all the neighboring roads, and of all the improvements which they require; this statement should be submitted to the sub-prefect, who should send it to the mayor, with his opinion thereon; the expense should be assessed upon the proprietors at so much per franc of their land-tax in the parish.

If it is difficult to induce the proprietors of a single parish to contribute to the maintenance of their farming roads, it is much more so to bring two parishes to unite in the repairs of their district roads. The rivalry often existing between them, the greater or less interest which they have in the use of the road, are obstacles in the way of the common good.

It is here that the authorities should interpose. Already, almost everywhere, the district roads have been usurped by the neighboring proprietors, and it is not by means of the local authorities that a redress of these grievances can be hoped for: for the members of the municipal councils and of the municipalities, themselves the largest proprietors in the parishes, are the first usurpers.

I would have attached to every department a superintendent of bridges and highways, whose duties should be confined to whatever relates to the district roads. A stranger to all local interests, he should prepare a plan of the district roads, should reduce within the limits of their own estates those who have encroached upon the public road, should prescribe the necessary repairs, point out the nature of the materials to be employed, and direct all the labor; and all his plans should be put in execution, after having been submitted to the engineers of the arrondissement, and approved by the chief engineer.

The parishes interested should pay the expenses by an assessment upon their revenue, their additional centimes, and partly by a payment in kind, with the approbation of the prefect.

The departmental roads, which form communications between the principal towns of a department, are of more general use and interest than those of which we have just been speaking; these should be maintained at the expense of the department itself; and the general council, to which funds are entrusted for this object, should make it one of its principal subjects of deliberation.

The great roads, which traverse all the departments, are of general interest, and should be established, superintended, and maintained by the government itself.

These four kinds of communication correspond to each other, and are bound together by a common interest; they may be regarded as arteries in the social body, which carry life to every part.

When these channels of communication shall be well directed and carefully maintained, transportation will become more easy, more prompt, and cheaper, all which is for the advantage of agriculture; we shall no longer see portions of the population enclosed within very narrow limits, and condemned to produce no more than they can consume, and to derive but small advantage from certain natural products, such as the wood which crowns the summits and covers the sides of almost all our mountains.

These communications, established through the country, will not only tend to facilitate the interchange of commodities and to increase production, but will have a favorable influence upon civilization. By bringing the inhabitants nearer to each other, they establish improving social relations between them; mutual assistance is rendered; mutual instruction afforded in the art of cultivation; and society, in its turn, profits by all these facilities for social union.

If to these communications by land, rendered as easy and as extensive as necessity requires, we add the immense advantages of navigation upon rivers and canals, agriculture will soon have little to ask of government.

There are few parts of France where canals cannot be made, or the navigation of rivers improved. When the grand scheme of navigation, which has been for three years provided for by a law, shall be executed, great means of communication will be opened; and it only remains to terminate this excellent system by branches, to secure to France all the benefit of navigation.

Then the varied productions of France will be conveyed to all points; the price of commodities will everywhere diminish, consumption will necessarily increase, and we shall not again see one district exposed to the scourge of famine, without others being able to supply it, except at a great expense.

CHAPTER XV.

ON FERMENTATION.

The process of decomposition commences in all the products of vegetation, as soon as they are ripe, or separated from the plant. Air, heat, and water, which before this concurred in promoting their formation and growth, become now the principal agents in the changes which they undergo.

The appearances and the new products resulting from the decomposition of bodies, vary according to the nature of their constituent principles.

Generally speaking, all vegetable substances decay when left to experience spontaneous decomposition; but when, by being exposed to mechanical pressure, those parts of the fruits which have been separated are again mixed, there arises a new product. The grape, for instance, rots upon the vine, whilst the juice expressed from it undergoes the vinous fermentation. It has for a long time been in the power of art to excite, retard, and modify decomposition, so as to form new articles of food and drink, for men and animals.

In vegetable products, all the principles are in a state of combination and saturation, one with the other: whilst the plant lives, its organic energies exert an influence over external agents, and preserve in their natural proportions the elements, which enter into the composition of the products.

As soon as a plant dies, or a fruit becomes ripe, a new order of things takes place; the different parts of the vegetable, being no longer influenced by the laws of vitality, become subject to the power of external agents; air, water, and heat exercise over them an almost absolute sway; oxygen, by depriving them of their carbon, destroys the proportions of their constituent principles; water produces the same effect by dissolving certain portions of the substance; and heat, by separating the particles, weakens their union, and facilitates the action of the two other powers.

According to the experiments of M. Gay-Lussac, the juice of grapes expressed in a vacuum does not ferment; but from the moment that the air is allowed admittance to it, fermentation takes place, and, without farther assistance from air, goes through all its stages.

Nearly all the methods made use of at the present time for preserving animal and vegetable substances from decomposition, are founded upon preserving them from the action of air, water, and heat, as I have already shown.

At the moment when the air, or any other external agent, deprives a vegetable of ever so small a portion of one of the elements which enter into its composition, the body becomes imperfect, the proportions between the principles are no longer what they should be, and decomposition cannot be prevented; there will then be formed new products by the union of the elements of the vegetable among themselves, or by their combination with the foreign bodies which act upon them.

When a dead body is disorganized by mingling together all its principles, decomposition proceeds either with greater or less rapidity, because the affinity between the parts being awakened, the several agents act more readily upon it.

Whenever man wishes to appropriate to his own use the product of a fermentation, it is necessary for him to interfere by directing the progress of it. The greatest number of fruits contain all the elements necessary for forming the vinous fermentation; but these elements are separate in them, and it is therefore necessary to mix and incorporate them together by the expression of the fruit, to produce this fermentation. The leaves and the woody fibre of plants are susceptible of putrid decomposition; but in order to produce it, they must be heaped together and moistened with water.

To produce a speedy fermentation of juices, it is necessary to collect them in a convenient quantity, and expose them to a determined degree of heat: without these precautions there will be, to be sure, decomposition, but often without any useful result.

The vinous fermentation is the most important of any, by reason of the usefulness of its products; I shall, therefore, speak particularly upon it.

The vinous fermentation takes place only when two principles of very different natures act upon and decompose each other: the result of this decomposition is alcohol. The first of these principles is sugar; the second is a substance very similar to animal gluten, which is found more or less abundantly in the various kinds of grain, and in the juice of some fruits.

Those fruits from which the juice is expressed to undergo the vinous fermentation, contain both these principles, but they exist in them separately: the extraction of the juice by pressure, mixes them intimately, and they then act upon and decompose each other.

In well-ripened grapes, the two principles exist in the exact proportions for producing the best results from fermentation; but in the grains which are equally used for the fabrication of spirituous liquors, the sugar is separated when the grain is made to germinate, before being submitted to fermentation.*

Some of the substances which by fermentation yield alcohol, require the addition of some foreign matter, in order that fermentation may commence and pass regularly through its various stages. The substance used for exciting fermentation, is called *leaven*, *ferment*, or *yeast*; and is almost always a partially fermented matter containing a large portion of the vegeto-animal principle. The scum which rises upon the top of liquids undergoing fermentation, or a fermented dough of wheat, rye, or barley, is used for this purpose.

Leaven, when mixed with any liquid containing sugar, continues to ferment, and communicates the action through the whole extent of it.

When the must of grapes has, by boiling and evaporation, been reduced to the state of an extract, the vegeto-animal principle contained in it is disorganized, and it cannot be made to ferment without the addition of some foreign body.

In order that fermentation may pass regularly through its several stages, and furnish a product free from all tendency to a spontaneous and final decomposition, it is necessary that the sugar and leaven should exist in the substance in suitable proportions:—if the proportion of sugar be too great, it will not be entirely decomposed, and the fermented liquor will retain a sweet taste: if, on the other hand, the quantity of leaven predominate, a part of it will remain undecomposed in the mass, and the nature of it

* In the process of germination, oxygen, which is the sole agent, combines with the carbon, and causes the developement of sugar in the grain. However, the fermentation of grain which has not first germinated, produces gradually the same results when distilled; as the first effect of fermentation as well as of germination is to throw off carbon.

being changed by fermentation, it will become in time sour or putrid, according to the nature of the body upon which it acts.

Generally speaking, the French grapes when ripe contain such proportions of sugar and the vegeto-animal principle as are well adapted for producing the vinous fermentation; but when the summer is cold or damp, the proportion of sugar is less, and the predominance of the mucilage renders the liquor weak. In this case, the small quantity of alcohol which is developed is not sufficient to preserve the wine from spontaneous decomposition, and at the return of heat, a new fermentation takes place, the product of which is vinegar. This evil may be easily obviated by artificial means: it is only necessary to add to the liquor such a quantity of sugar as would naturally have been found in it, under usual circumstances.

For ascertaining the quantity of sugar which belongs to the must of well-ripened grapes, the following hints will be sufficient.

In the south of France, the grapes usually arrive at a state of perfect maturity, and if the fermentation be well conducted, the wine will keep well; but in the north, however favorable the season may be, the grapes never become perfectly ripe. I have always observed that the wine of the south, which had been well fermented, marked upon the aërometer some fractions of a degree below the specific gravity of water, whilst the new wines of the north rarely cause the aërometer to descend to the same degree.

Another important circumstance by which we must be guided in ascertaining the quantity of sugar necessary to be employed, is the degree of concentration of the must: this varies with every vintage, and the aërometer has often indicated to me a difference of concentration, varying from 2° to 4° (= specific gravity of 1.014 to 1.029,) in the must procured from the same vineyard, according to the state of ripeness which the fruit had acquired; the heaviest must being furnished by the ripest grapes.

In Touraine, and upon the borders of the Cher and the Loire, the weight of the must varies from 8.5° to 11°; (= specific gravity of 1.063 to 1.083.) I have observed it in the south to range between 10° and 16° (= specific gravity of 1.075 to 1.125.) Having once ascertained the specific gravity of the must obtained from perfectly ripe grapes, it is only necessary to bring to the same weight, by the addition of a sufficient quantity of sugar, the must of such grapes as grow in seasons less favorable to their maturity.

In 1817 the grapes of Touraine did not ripen well, and consequently the must from my vintage, which in favorable years marks 11° (= specific gravity of 1.083,) stood only at 9° (= sp. gr. 1.067.) I raised it to 11° (= sp. gr. 1.083,) by the addition of sugar, covered the tub with boards and woollen cloths, and left it to ferment. The wine cleared itself through the vent of the vat, and had nearly as much strength as the southern wines, whilst that which had been put into a tub without the addition of sugar was as flat and thick as the coarse red wine of such vintages usually is. The last kind of wine usually sells for fifty francs per butt, and I have refused sixty-four for mine, preferring to keep it for my own table. The wine to which the sugar had been added was as clear as some that had been four years in the cask, and was much more agreeable to the taste. Twenty butts of wine prepared in this way require one cwt. of sugar. The mode is as follows.

As soon as the grapes are pressed and the must poured into a vat, a portion of the same liquid is put into a boiler and set over the fire, where it is sufficiently heated to dissolve the sugar: as soon as the solution is completed it is thrown into the vat, and the whole well stirred: this operation is repeated till all the quantity of sugar to be employed is combined with the liquor.

Some authors advise, that the must itself be boiled till it is reduced to one half; but I am not of the opinion that this is the best mode of proceeding. Boiling reduces a portion of the vegeto-animal principle to a concrete state, and thus affects the fermentation of the liquor: I have always limited the degree of temperature to which the must should be heated to 35° or 40°.* In the northern parts of France, where grapes never ripen, they may by means of sugar carry the concentration of the must one or two degrees farther than that of grapes which grow in the best years, and the wine will thus be rendered far richer and likewise less liable to decomposition.

The following are the advantages to be derived from this method.

[* No scale is mentioned: if the one referred to be the centigrade, the equivalent numbers upon Fahrenheit's are 95° and 104°; if Reaumur's, 110¾° and 122°.—Tr.]

1st. When the liquor in the vat is heated by means of the solution of sugar, the temperature is raised to 12° or 14°,* and this causes the fermentation to take place more speedily.

2d. By covering the vat, the liquor is secured from experiencing those variations of atmospheric temperature, which may either hasten, retard, or suspend fermentation.

3d. The heat developed in a close vat is more intense than that in an open one, and the decomposition of the must is consequently more perfect.

4th. The addition of sugar gives rise to an additional quantity of alcohol.

5th. The head of the liquor is much less apt to become sour.

6th. The wine is more equal and less susceptible of change.

7th. The loss of alcohol by evaporation is less than in uncovered vats.

As next to that of corn the harvest of wine is the most important one, inasmuch as it forms our principal article of commerce with foreign countries, too much care cannot be taken in the manufacture of it.†

It is customary with most of our proprietors of vineyards to plant upon the same soil vines of different kinds of grapes, the fruits of which do not arrive at maturity at the same time. This custom is particularly practised in those vineyards which produce wines of middling quality; and it has been introduced and continued in them, because the different kinds of vines do not flower at the same time, but are some of them earlier than others, and some of them more sensible to the influence of the changes of the at-

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[* If the centigrade thermometer, the corresponding degrees of Fahrenheit's are 53.6° and 57.2°; if Réaumur's 59° and 63½°. — Tr.]

† The mean value of the products of the vineyards of France from 1805 to 1809, was about 36,000,000 hectolitres of wine, (= 7,548,285 pipes, 1 hhd. 27 gals.) According to an examination afterwards made by the board for the levying of indirect duties, which claimed some right over this liquor, the valuation here mentioned is believed to be far short of the truth.

Vineyards which had then been recently planted, and consequently produced but little wine, now afford abundant crops; and as new ones are constantly planted, I am convinced that the product of the vintage is very considerably augmented. It is I think probable, that the harvest of wine equals at this time nearly 50,000,000 hectolitres, (= 10,483,737 pipes, 1 hhd. 5 gals.)

mosphere; it therefore rarely happens that either one or the other does not bear. This mixture, however, in the same vineyard is injurious to the quality of the wine; for although the several kinds of grapes do not ripen at the same time, yet they are all harvested together.

Grapes even of the same kind do not all ripen at the same period: the difference of exposure, and the vegetative vigor of the vine advance or retard the ripening several days. By gathering them all at once and subjecting them to the same fermentation, the wine obtained is far inferior to what it would be, if the grapes were culled, and only those pressed which had arrived at maturity.

In most of the French vineyards, harvesting is commenced early in the morning, and continued throughout the day, till the vintage is ended; as fast as the grapes are brought in they are pressed, and the liquor thrown into the vat. Now it is well known, that grapes when moistened with dew or rain undergo a less speedy and thorough fermentation, than when they are well dried; and it is likewise an established fact, that when the weather is hot during the vintage, the fermentation of the grapes is not only more rapid but better than in cooler weather.

It appears, then, that grapes should not be gathered till the heat of the sun has dissipated the dew; it is, however, difficult to wait for all the favorable circumstances for a harvest at the time of gathering grapes in our large vineyards; they can only be seized upon for the manufacture of the most delicate and costly wines. The coarse red wines, like those from the banks of the Loire and the Cher, are sought for in commerce only in proportion to the depth of their color, because they are principally used for mixing with white wines: the new wines are preferred for this purpose, from their containing a portion of mucilage, which gives to the mixture a delicate taste, and those wines which have lost this principle in the casks are rejected, though better for drinking, because they are less fit to be mixed with dry white wines.

By improving the fermentation of these coarse wines they would be rendered much better for drinking without any mixture; but the only sale there is for them would be closed, as they would no longer be bought, as they are now, to form, by being mixed with the white wine of Sologne, the principal drink of the people of Paris.

In some wine countries it is customary to pluck the grapes from the stalks, in others the must is fermentea with the stalks; the mode should vary according to the nature of the grape, and the use for which the wine is designed. In the south, they pluck the grapes for wine that is destined for the table, and they do not pluck them for wine which is to be *burned* or distilled.

M. Labadie, the proprietor of a vineyard, and a very enlightened man, states that the wine made from the white grapes of Champagne is brisker, and less likely to become oily, when made of fruit that has not been plucked.

Don Gentil is convinced, from his own experience in wine-making, that fermentation proceeds with a greater degree of energy and regularity in must from grapes that have not been plucked, than in that of plucked grapes.

The stalks contain a slightly bitter principle, which is communicated to the wine, and improves the taste of such as is naturally flat, and at the same time fermentation is facilitated by them. According to this, the fruit should be separated from the stalks whenever the must can be made, without any addition, to undergo a good fermentation, and produce first-rate wine; and the stalks ought not to be removed from such grapes as usually afford only an ordinary, clammy kind of wine, which does not keep well. Nor should such grapes as contain a large portion of sugar be separated from the stalks, as they will then produce too sweet a wine.

The temperature of the cellars in which the must is fermented is seldom equal to 12° of Réaumur, (= 59° Fahr.) and the heat of the atmosphere, and consequently that of the grapes does not often indicate that degree; and yet the must cannot be well fermented at less than from 52° to 59° Fahr., and in order to insure a perfect fermentation the heat should rise thus high.

The cellars might be heated by stoves, and the grapes placed in them before being pressed, till they had acquired the necessary degree of warmth; or what would be better still, the must might be heated in boilers before being thrown into the vat; in this way fermentation would take place in a shorter time, and be more lively and complete.

As soon as the liquor is in the vat, it should be closely covered over with boards and old coverlids, or, in preference, with the furniture belonging to the manufacture of wine. By intercepting all communication with the external air, the must is secured from being affected by the changes of temperature, which are unfavorable to fermentation, the head of the liquor is prevented from becoming sour, and at the same time a constant and equable heat is kept up during the operation. Should the fermentation appear to relax, the liquor must be stirred with a bough, so as to mix with it the leaven which has formed upon the top, and by this a new impulse will be given to the process. Good effects arise also from keeping a bough of the vine immersed in the liquor by means of boards or a string.

The ancients carefully separated all the various juices which they could obtain from grapes, and fermented them singly: the first, which was procured from the ripest grapes by the slightest pressure, furnished their finest wines, called by them *protopon, mustum sponte defluens antequam calcentur uvæ.* Baccius describes this process as practised by the Italians, thus: *Qui primus liquor, non calcatis uvis, defluit, vinum efficit virgineum, non inquinatum fæcibus; lacrymam vocant Itali; cito potui idoneum, et valde utile.*

When the wine has fermented sufficiently in the vat, it is put into hogsheads, and there undergoes an insensible fermentation, which completes the operations; by being kept undisturbed it settles and becomes clear.

In those countries where grapes arrive at perfect maturity, wine can be kept in the vat in which it is fermented, without any danger of alteration; and this is done in most of the southern cantons; it is however necessary, in this case, that the joinings of the boards with which the vats are covered be plastered over with mortar, that the air may not gain admittance.

Wine makes better when in large quantities than when divided in casks; but in those countries where the grapes contain less sugar, and where, after fermentation in the vat, the wine still contains much mucilage, if putting it into casks is delayed, the fermentation will very soon be followed by the second, and the product of this last is vinegar: the existence of alcohol and mucilage is sufficient to occasion this change.

The casks which receive the wine from the vat should be arranged in a place where the temperature is cool and uniform, and where they will not be exposed to being shaken or jolted.

When fermentation has not been completed in the vat, it is continued in the casks, and all the principles contained in the must, which are not susceptible of concurring in the fermentation, are either precipitated to the bottom, or deposited upon the sides. All the methods adopted for clarifying wine are founded upon this principle. The mucilage, tartar, and extractive matter which must holds in solution, are only suspended in well-fermented wine, and are gradually deposited from it. The burning of brimstone in the casks facilitates the formation of the deposit, and racking separates the deposited matter from the liquor. By the addition of isinglass or any similar substance to wine, all the particles which remain suspended in it are seized and united together, and can thus be removed.

All these operations tend to free the wine from foreign substances, and to prevent it from becoming changed, and at the same time to preserve all the taste and good qualities which belong to it. The red wines lose a part of their coloring matter by age, and, if the wine has been well clarified, this change can be accelerated by exposing bottles filled with it to the heat of the summer's sun. In this case the coloring matter is precipitated in pellicles, and the wine becomes of the color of an onion skin, but undergoes no other change: I have seen this done in experiments upon the best wines of Languedoc.

When wine is put into new casks, it dissolves a portion of the tannin and extractive matter contained in the wood, and is thus colored and decomposed, especially if the wine be not very strong. The liquor in this case acquires what is called the *taste of the cask*. The color which brandy receives in the cask is from these same principles. To obviate this inconvenience, the inside of the hogsheads should be charred; the wine will then be preserved free from alteration.

The most common degeneration of wine is its becoming sour, by which it is converted into vinegar: this does not, however, take place if the wine has been completely freed from the mucilage and extract contained in the must, but fermentation is seldom thorough enough to disengage entirely, and render insoluble these principles, especially if the grapes are not well ripened.

This degeneration may be retarded, and even prevented by keeping the liquor in closely stopped casks set in a cool place, where they will be free from motion, as every shake of the cask mixes again with the wine the substances which have been precipitated from it.

The acidification or acid degeneration does not take place in sweet wine, as there still exists in that a portion of sugar which renders it incapable of undergoing any other than the vinous fermentation; but when this principle is entirely decomposed, a sufficient degree of heat, the contact of the atmosphere, and the presence of a little mucilage will cause the acidification of the greater number of wines.

The acid degeneration generally takes place when the grapes do not contain sugar enough to decompose all the vegeto-animal part: it occurs necessarily in wine which holds in solution mucilage and extract; and this is always the case when the sugar contained in the grapes is not sufficient to develope much alcohol, and precipitate these substances.

It appears, from well-confirmed experiments, that the contact of the air and the existence of mucilage and extract in wine containing but a small quantity of alcohol, will produce spontaneous acidification.

Stahl states, that if the flowers of the rose-tree, or the lily of the valley be moistened with alcohol, and the vase containing them shaken occasionally, vinegar will be formed. He likewise informs us that when the acid of lemon is saturated with lime, if alcohol be thrown upon the remaining portions of the lemon juice, the mixture, when exposed to a gentle heat, produces vinegar.

The best wine may be converted into vinegar by soaking or steeping green wood in it: the process described by Boerhaave is founded entirely upon this principle: he employed for the purpose the branches of the vine and the stalks of grapes.

The mash of grapes, the lees of wine, and the residuum of distillation well dried and moistened with a little alcohol and water, undergoes the acetous fermentation. The juices of most other fruits, as well as of grapes, may be made, by fermentation, to produce a spirituous liquor to be used either as drink, or to furnish alcohol by distillation.

The practice of fermenting various kinds of bread corn, particularly rye and barley, has existed for a long time, and from them are produced, by distillation, the liquors that are most used in those countries where the vine is not cultivated.

Since the culture of the potato has been so astonishingly extended in Europe, the uses of it have been multiplied, and it is now fermented for the purpose of obtaining alcohol by distillation. The first process which was followed in this manufacture is still practised upon the banks of the Rhine, and in Germany; by the second, for which we are indebted to modern chymistry, the fecula is converted into a saccharine substance, and thus rendered susceptible of the vinous fermentation.

I shall describe concisely both of these processes, because they may be made to enter advantageously into a system of labor for an extensive farm, both on account of the liquor obtained, and of the food which is furnished for animals by the mash.

The old method may be reduced to the two following operations.

A cask which will contain about two English hogsheads is set up on one end, and a square opening made in the head, through which the potatoes are thrown in; another small opening is formed in one of the staves on a level with the bottom of the cask, and serves for taking the potatoes out. The potatoes are boiled by steam introduced into the cask by a tube passing through the lower end of it. As soon as the potatoes are boiled, they are crushed as perfectly as possible between two wooden cylinders, each of which is furnished at one end with a driving wheel, put in motion by a crank. The pulp of the potatoes is thrown into a tub where it is made to ferment: the vinous fermentation would not however take place in it, if it were not excited by the addition of leaven; the leaven used is made in the following manner.

To 4 pounds of malt are added one pint of beer yeast, and about 44 pounds of the potato pulp; these are worked carefully together and diluted with ten or eleven gallons of water at the temperature of 40° Réaumur, (= 122° Fahrenheit,) and the vessel containing the mixture is covered over. The paste thus made ferments and rises, and at the end of twenty-four hours, it is mixed with the body of pulp deposited in the vat, some hot water is thrown in upon it, and the whole is stirred constantly, till the temperature of the liquid stands at from 15° to 18° Réaumur, (= to $65\frac{3}{4}$° and $72\frac{1}{2}$° Fahrenheit,) and the specific gravity marks 6° or 7° upon the aërometer, (= specific gravity of 1.044 to 1.052.)

During fermentation, care must be taken that the temperature of the place should not vary more than from 20° to 25° Réaumur, (= to 77° and 88° of Fahrenheit;) and without this the fermentation will languish and never be complete. When all circumstances are favorable, the fermentation may be terminated the third day, but it is most commonly prolonged till the fourth or fifth.

If the operation be well conducted, the fermented liquor will mark only 0 to 1° of the aërometer, (= specific gravity of 1.000 to 1.007;) the more complete the fermentation is, the less will be the specific gravity of the liquor.

This action should never be violent, as it is well known that in such cases the product is less than when it is slow and regular: whilst it is going on, all the fragments of the potatoes rise to the top and form a crust, which must be separated towards the middle to allow of the escape of the gas.

In a manufactory where the processes are constantly going on, it is not necessary to form a new ferment for each operation; about three gallons may be reserved to be made use of when again required.

Distillation should be so conducted, that the alcohol may pass off equally and regularly, and this can only be done by a judicious management of the fire: the variations of the heat applied to the boiler accelerate or retard distillation, and consequently the alcohol in these two cases is not produced in the same degree: it often happens when the fire is too forcible, that the liquid contained in the boiler is itself forced into the worm of the still.

It is of importance in a distillery to have an abundance of water, both that the casks may be thoroughly rinsed after each operation, and for cooling the worm of the still, as without this precaution a portion of the alcohol formed would be lost by evaporation.

By this method four sacks of potatoes yield upon an average 13 gallons and a fraction of brandy, at 20° (= specific gravity of 0.935,) of the aërometer; if all circumstances are favorable, they may afford 15 gallons.

When wines are dear and potatoes cheap, the manufacture of brandy in this method, is found very profitable: in the year 1816, the advantages arising from it were very great, and even under ordinary circumstances, it may be done with profit.

The residuum of the distillation, mixed with mustard or turnip cakes, forms excellent food for horned cattle, and is eaten by them with avidity.

The fecula or starch of potatoes was first converted into a fermentable saccharine substance by M. Kirchoff, of St.

Petersburgh; it was done by means of boiling it a long time in a weak sulphuric acid; the result has been seized upon, and made the basis of an advantageous mode of rendering fecula fermentable, and extracting from it a spirituous liquor. This process has been brought to such a perfection in France, that the products of the establishments sustain a competition with those of wine and brandy, though the latter may be selling in commerce at a low rate.

The first step is to mix, in a leaden boiler, concentrated sulphuric acid with water, in the proportion of 3 of acid to 100 of water: the temperature of the liquor is then raised to boiling, and the fecula is made, by means of a hopper, to fall gradually into it: the mixture is then stirred forcibly and the boiling at the same time continued. After six hours the ebullition is stopped; the acid is then saturated with chalk, and a sulphate of lime is thus formed and quickly precipitated.

When all the deposit has formed, and the liquor become clear, it is carefully racked off and thrown into the vats in which it is to be fermented. These vats are five feet deep and four and a half in diameter; they are situated in a place where they can be kept constantly at a temperature of from 77° to 88¼° Fahrenheit.

The density of the liquor should be from 7° to 8° of the aërometer, (= specific gravity of 1.052 to 1.060.) As soon as the fermentable liquor has acquired the temperature of the distillery, there is mixed with it 44½ lbs. of the beer yeast which is brought from Holland: fermentation takes place in a short time and continues several days; it sometimes relaxes in energy, but in a few days the action is renewed with increased activity.

1 cwt. of potatoes ought to yield from 5¼ to 5¾ gallons, and this will be the case when the process is well conducted. Starch sells in Paris at from 8 to 9 francs (= about 144 and 171 cents) per cwt.

This brandy has neither a bad taste nor odor, and the manufacturers of liquors prefer it to that made from wine.

CHAPTER XVI.

OF DISTILLATION.

The art of distilling wine to extract from it the spirituous principle, has made known a new product, which is used not only as drink, but as one of the most useful articles employed in the arts.

The product of the distillation of wine is known in commerce under the names of brandy, alcohol, spirit of wine, &c. and the apparatus in which the process is carried on is called an alembic.*

The importance of vineyards has been greatly increased by the discovery of the art of distilling wine; before that the vine was cultivated for no other purpose than that of furnishing a strengthening and agreeable drink: distillation disengages from this liquor a volatile, inflammable, spirituous principle, forming a much more active drink which has come into general use throughout nearly all Europe; it is likewise used in the arts for dissolving resins and forming varnishes, to preserve fruits, dissolve the perfumes of plants, and to establish some new processes.

Most of the white and a part of the red wines are now employed for distillation: the good red wines are reserved for the table.

Before quitting so important a subject, I will sketch, in a few words, all which had been done in the way of distilling wine before the invention of the new apparatus, which has caused such a revolution in the art of distillation, that it may be said to have been created at the present day.

The ancients had very imperfect ideas of distillation. From the evidence of Raymond Lully, Jerome Rubeus, and John-Baptist Porta, there can be no doubt, that the ancients understood the art of extracting the odoriferous principle by the steam from water; but they made use of

* The names *brandy* and *spirit of wine*, employed to designate the two extremes of the same liquor as they are found in commerce, have been supplied in the new chymical nomenclature by the generic term *alcohol*. However, as in common language the names *brandy* and *spirit of wine* are given to substances differing widely in the uses to which they are applied, it is to be feared that commerce will not be willing to comprehend them under the same denomination; as it is not enough that they are of the same nature, if the price and the use establish a wide difference between them.

nothing which deserved the name of apparatus. Dioscorides says, that in distilling resin it is necessary to collect the volatile particles upon cloths placed over the vase.

The first navigators of the islands of the Archipelago procured fresh water by receiving the vapor of salt water in sponges arranged upon the vessels in which it was boiled. (See Porta, *De Distillatione*, Cap. I.)

The word *distillation* did not possess, amongst the ancients, any signification analogous to the import of it at the present time: it was used by them as a generic term, comprehending filtration, fluxation, sublimation, and all the similar operations to which we have assigned various names, and for each of which we use a particular kind of apparatus. (Jerome Rubeus, *De Distillatione.*)

During the time of the republic and under the reign of the kings, the Romans appear to have known nothing of distilled spirit: Pliny, who wrote during the first century of the Christian era, makes no mention of it; he has left us a very good treatise upon vinegar and wine, but he says nothing of distilled liquor, though he speaks of wine in all its forms: Galen, who lived a century after him, uses the word distillation in the sense which I have mentioned before.

The art of distillation in all probability owes its origin to the Arabians, who have, from time immemorial, formed extracts of the aroma of plants, and who brought their modes of proceeding successively into Italy, Spain, and the south of France: it even appears that the word *alembic* is found for the first time in their writings, and has its origin in their language; it was used by them before the tenth century; for Avicenna, who lived at that time, made use of it to explain the nature of the disease called *catarrh*, which he compared to a distillation in which the stomach is the cucurbite, the head the cap, and the nose the beak by which the humors flow out.

Rhazes and Albucazin describe particular processes for extracting the aromatic principle from plants; it appears that the steam was generally received into the cap of the still, which was cooled by wet cloths.

It is evident that Raymond Lully, who lived in the thirteenth century, was acquainted with distilled spirit and alcohol, for in his work entitled *Testamentum novissimum*, at page 2d of the Strasburg edition, 1571, he says: "Recipe nigrum nigrius nigro (red wine) et distilla totam aquam ardentem in balneo; illam rectificabis quousque sine phlegmate sit." He states that seven rectifications are employed, but that three are sufficient to render the alcohol inflammable, and to prevent its leaving any aqueous residuum.

The same author shows elsewhere the mode of separating the water by means of a dry fixed alkali. (See Bergman's *Opuscula physica et chymica*, Leipsic edition of 1781, Vol. IV. page 137.) Towards the end of the fourteenth century, Basil Valentine proposed the use of quicklime for the same purpose.

In all his works Raymond Lully speaks of a preparation of distilled spirit which he calls *quinta essentia*, whence is derived the word *quintessence:* he obtained it by repeated cohobations made at a gentle heat during several days, and by redistilling the product. Raymond Lully and his sucessors attached great virtue to this quintessence, which they made the base of all their alchymical labors.

Arnold of Villanova, a contemporary of Lully, speaks much of distilled spirit, but not in such a manner as to justify the conclusion of his being the inventor of the process by which it was obtained; he cannot however be denied the honor of having made the happiest application of the properties of distilled spirit, and particularly of simple and compounded wine, both in medicine and pharmaceutical preparations. (*Arnaldi Villanovani Praxis: Tractatus de Vino;* cap. *De Potibus*, etc.; edit. Lugduni, 1586.)

Michael Savonarola, who lived at the commencement of the fifteenth century, has left us a treatise (*De conficiendâ Aquâ Vitæ*,) which contains some very remarkable things respecting distillation. He first remarks, that those who proceded him did not generally know the following process for distillation. This process consists in putting the wine into a metal boiler, and receiving the vapor in a pipe placed in a bath of cold water; the condensed vapor flowed from the pipe into a receiver.

Savonarola observes, that distillers placed their establishments near a stream of water, that they might always have fresh water at their disposal. The ancients called the spiral worm of the still *vitis*, on account of its windings. (See Jerome Rubeus.) For closing the joinings of the apparatus, they employed a lute made of lime and white of eggs; or one of flour paste and paper.

Savonarola adds, that in his day the use of glass cucurbites was introduced, that the distilled spirit might be more pure; and that they were covered with a cap which was cooled with wet cloths. He advises the use of large caps, as increasing the surface. (Cap. V.)

The same author says, that the neck uniting the boiler and the head should be as long as possible, in order that the spirit may be produced at once, and adds, that one of his friends placed the boiler on a level with the ground, and the cap upon the roof of the house.

Amongst the various means which he gives us, by which we may judge of the degrees of strength of distilled spirit, he mentions the following as being practised in his time. 1st. Cloth or paper is dipped in the liquor, and then set on fire; if the flame of the liquor burns the cloth or paper, the liquor is said to be of a good quality. 2d. The liquor is mixed with oil to see if it will swim.

Savonarola treats at length of the virtues of distilled spirit, and gives some processes for combining with it the aroma of different plants and some other principles, both by maceration and by distillation, and for thus making what he calls *aqua ardens composita*.

Jerome Rubeus, who made many experiments in the way of distillation, describes two very curious processes, which he found, in fact, in ancient works: one of these processes consisted in receiving the steam into long, twisted tubes plunged in cold water; the other, in placing over the cucurbite a cap of glass, with a beak. It is remarkable that Jerome Rubeus preferred the apparatus with the long tube, as he obtained by it, with a single distillation, very pure spirit of wine, which could only be obtained, with the other kind, by repeated distillations. (*De Distillatione*, § 2, cap. II. edit. de Bâle, de 1568.)

John-Baptist Porta, a Neapolitan, who lived towards the end of the sixteenth century, published a treatise, *De Distillationibus*, in which he viewed the operation in all its connections, and as applied to all the substances, which are capable of undergoing it; he described the different kinds of apparatus by which there might be obtained at pleasure, and by a single heat, distilled spirit in all its degrees of strength.

The first kind of apparatus consists of a tube twisted spirally, and fitted to the top of the boiler; the second is composed of caps placed one over the other, each one being furnished with an opening in the side, to which is fitted a tube communicating with the receiver: he observes, that by this means there can be obtained at pleasure all the degrees of rectification, since the aqueous particles are condensed in the lower caps, whilst the spirituous parts rise to the upper one. These methods differ very little from those which, according to Jerome Rubeus, were in use among the ancients.

Nicholas Lefebvre, who lived towards the middle of the seventeenth century, published, in 1651, a description of the apparatus with which he obtained, at a single operation, the purest alcohol.

This apparatus is composed of a long funnel formed of several pieces joined together in zigzags; one end of it is fitted to the boiler, and the other to the cap: the beak of the cap transmits the vapor into a pipe, which passes through a cask filled with cold water; in this pipe the vapor is condensed and flows from it into a receiver.

Dr. Arnaud, of Lyons, in his *Introduction à la Chimie ou à la vraie Physique, imprimé en* 1655, *chez Cl. Prost, à Lyon*, has given us some excellent instructions in regard to the construction of furnaces, the composition of flues, the mode of regulating the fire, calcination, and distillation, which he calls a moist sublimation. He advises the use of shallow boilers as facilitating evaporation; he speaks of the conversion of distilled spirit into the spirit of wine, by repeated distillations in a water bath, such as is now employed for distilling those substances, the spirituous portions of which are vaporized at a degree of heat less than that of boiling water. He also speaks of the vapor or dew bath.

John Rodolph Glauber, in his treatise entitled *Descriptio Artis Distillatoriæ novæ*, printed in Amsterdam in 1658, by John Janson, makes known to us some proceedings, in which we find the germ of most of the operations, which are now carried to such perfection amongst us. One of them consists in transmitting the vapor which escapes by distillation into a vase surrounded with cold water: the vapor which is not condensed in this first vessel, passes through a bent tube into a second, from that to a third, and so on till the whole is perfectly condensed. It is evident, that by means of such an apparatus, spirits of wine of different degrees of rectification may be obtained, according as the condensation takes place in the first, second, or third of the vases, plunged in cold water.

In another kind of apparatus, he placed a retort of copper in a furnace; the beak of the retort passed into a close cask filled with the liquor which he wished to distil; a tube, fitted into the upper part of the cask, was joined to a worm placed in another cask, which was filled with cold water. By this arrangement, the liquid contained in the first cask was continually falling into the retort, where it was heated, and thus the whole contents of the cask were at length raised to a sufficient degree of heat to produce distillation, and thus a considerable volume of liquor was heated with a small furnace, and at a trifling expense. Glauber applied this ingenious apparatus to heating baths.

Philip James Sachs, in a work printed at Leipsic, in 1661, under the title of *Vitis viniferæ ejusque Partium Consideratio*, &c., has given us a complete and very valuable treatise upon the culture of the vine, the nature of the soils, climates, and exposure adapted to the growth of it; the manner of making wine; the comparative wealth of different nations in this article of culture; the differences and resemblances of the several methods used amongst each of them; the distillation of wines, &c. In the last chapter we see what will only detain us for a moment, that the ancients had many methods of extracting spirit of wine, and that these consisted entirely either in vaporizing it at a gentle heat, depriving wine of its water by calcined alum, putting moistened cloths over the alembic, placing ice upon the cap of the alembic, that the most subtle vapors might not escape, or, finally, in terminating the boiler by a very long neck.

The same author speaks also of the quintessence, *quinta essentia*, and gives various modes of extracting it. "Ut vero spiritûs vini alcool exaltetur, variis modis tentârunt chimici; quidam multis repetitis cohobationibus; aliqui, instrumentorum altitudine; alii, spongiâ alambici rostrum obturante, ut, aquâ retentâ, soli spiritus transirent; non multi, flammâ lampadis, ut ad summum gradum depurationis exaltaretur."

Moses Charas, in his *Pharmacopœia*, printed in 1676, describes the apparatus of Lefebvre, and adds some improvements to it; he adapts a refrigerator to the cap. We may still see, in the *Elémens de Chimie* of Berchusen, printed in 1718, and in those of Boerhaave, which appeared at Paris in 1733, several processes detailed, by which very pure alcohol may be obtained at a single distillation; but

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in all of them the vapor passes through long tubes, that the aqueous particles may be condensed, and that the last result may not be received till it is as light and pure as possible.

Subsequently to these authors, many others have written upon the subject of distillation, and have proposed and executed many alterations upon their methods; instead, however, of improving upon the happy idea of their predecessors, who aimed at obtaining at pleasure all the degrees of alcohol by successive condensations of the watery particles mixed with the alcohol, they confined themselves to varying the form of the boiler, the retort, or the worm, and thus the art of distilling was nearly in a retrograde state for almost a century.

This art was stationary a short time since, when a process was generally adopted, which, though far from being founded upon true principles, produced the desired effect. In this process the alcohol of the different degrees of strength was obtained by repeated distillations. Such was the state of the art towards the end of the last century; at that period the apparatus most generally employed for distilling was composed of three pieces: the metal used was copper; the boiler, which contained about 50 gallons of wine, was contracted in size towards the upper part; a cap was adapted to the orifice, and communicated by a long pipe with a worm; the worm was placed in a cask which was kept full of cold water, and thus condensation of the alcoholic vapor was produced.

This coarse apparatus possessed many defects, the first of which was, that all the vapors raised by the action of the fire passed into the worm, where they were condensed; thus the aqueous particles were mixed with those of alcohol, and flowed with them into the receiver, forming a weak distilled spirit, which required to be submitted to a second distillation before it could be brought to a due degree of strength.

The second inconvenience arising from this apparatus, was the incompleteness of the condensation; for as the water in the cask soon became heated, there consequently ensued a great loss of alcoholic vapor, which passed off into the atmosphere of the distillery.

The third fault was, that, as all the vapors, which rose from the boiler, passed immediately into the worm, where they were condensed, it was necessary so to regulate the fire, that the alcoholic particles alone might be evaporated; a few moments of too great heat were sufficient to cause the ascension of a great mass of aqueous vapor, by which the alcohol was rendered deficient in strength; the necessity of watching the fire, therefore, made the operation a very difficult one.

The union of so many faults in the apparatus, rendered it impossible to extract the last portions of alcohol remaining in the wine, without their being loaded with an immense quantity of aqueous particles: this last product of distillation was carefully separated under the name of *small water*, and redistilled with a new portion of wine.

The spirit obtained by the above process always has a burnt taste, and is rarely very clear; this arises from the difficulty of regulating the fire, and the still greater difficulty of obtaining, without increasing the heat too much, all the alcoholic particles contained in the wine.

If to the above-mentioned faults we add, that the furnaces of these alembics were badly constructed, that they presented no means either of regulating the heat, or of applying it equally to the whole body of the liquor, we shall see that the art of distilling was yet in its infancy.

I was aware of these defects, and attempted to correct them, and in consequence I caused to be made large boilers of but little depth, that as great a surface as possible might be presented to the fire; I surrounded the cap with a bath of cold water; this produced the first condensation, and separated the aqueous particles, which fell back in drops or streams into the boiler; I increased the number of windings in the worm, and enlarged the bath-cask, that the water might not so soon become heated. These alterations were approved of, and distillation was established upon these principles. My apparatus and that of M. Argand, who had wonderfully improved the furnace, was employed with success during fifteen or twenty years.

In the first years of the present century, the art of distillation was established upon new principles, and it has gone far beyond all that was before known and practised. A chymical apparatus, by means of which vapors or gases were made to pass through liquids which were to be saturated with them, gave to Edward Adam the first idea of his apparatus for distillation; a knowledge of the fact that aqueous vapors are condensed at a degree of heat which does not effect a like change in alcoholic vapor, furnished him with the means of completing his apparatus.

The chymical apparatus suggested to Adam the idea of conducting, by the aid of a copper tube, the vapor which rises from a boiler of wine placed over the fire of a furnace, into a second boiler of the same liquid, which is thus heated to the boiling point : the vapor from this second boiler may be carried into a third, in which ebullition will likewise take place ; and thus by means of a fire kept under one boiler, distillation may be carried on in two or three, provided they are well closed. This mode of transmitting heat is now practised in most foreign distilleries, and it is called *heating by steam.*

Edward Adam, by the process just detailed, made a great saving of fuel, and was sure that the spirit obtained would always be free from a burnt taste. He also saved time and labor, for the workman whose business it was to attend one furnace, accomplished much greater results, than if that fire caused the evaporation of but one boiler. These were certainly great improvements, but it was necessary to go still further, and to find the means of obtaining alcohol in its greatest possible purity by freeing it from all aqueous particles, and this he did by applying to his apparatus the second principle which we have already specified. "By making," he says, "the alcoholic vapor which rises out of the last boiler pass into vessels immersed in a bath of cold water, the aqueous vapor will be condensed, and I can then bring it back again into the first boiler, to be there redistilled, whilst the alcoholic vapor will pass out of these vessels, without being condensed, into the worm, where it will undergo condensation."

Proceeding upon this reasoning, founded upon positive facts, he adapted a tube to the upper part of the last boiler; this tube conducts the vapor into a first condenser, which is of a spherical form and immersed in a water bath ; in this, a part of the aqueous vapors are resolved into a liquid form, and this liquid is carried by a pipe into the wine of the first boiler, to be redistilled and deprived of the small portion of alcohol which it still holds in solution ; the vapors which cannot be condensed in the first receiver pass into a second, where a new condensation takes place in consequence of the temperature being less elevated ; from the second it goes into a third, and thence into a fourth ; that which is condensed returns, as I have just said, into the boiler, where, by a new distillation, it is deprived of all its remaining spirituous portions.

The vapor in passing through the condensers gradually loses its heat, and thus the water is precipitated, and the alcohol being deprived of nearly all the water which had risen with it, when it is at length condensed in the worm, marks the highest degree of rectification.

We see, from the foregoing statement, that by this process there can be obtained at will, and by a single operation, all the degrees of rectification found in commerce; each condenser yields a different degree, and, by withdrawing successively the product of each one, we shall procure a spirituous liquor, varying through all the degrees from brandy to the purest alcohol. By conducting the vapors directly into the worm, without causing them to pass through the intermediate condensers, that degree which forms good brandy of commerce is produced.

Such are the principles which chiefly constitute the process of Edward Adam; but independently of the application of these principles, he has added some improvements to his apparatus, which render it more perfect.

By the aid of stop-cocks and pipes, he directs the vapor at pleasure into a small worm of experiment, there to undergo condensation, in order that the degree of rectification may be judged of as often as necessary. He also interposes a worm between the condensers and the worm which is in the water-cask; the upper worm is immersed in the wine, which receives from it a degree of heat which hastens its ebullition when the boilers are filled. This first worm so condenses the alcoholic vapor, that it flows liquid into the second worm, and heats but little the water bath in which the second worm is immersed.

From these arrangements there arise three great advantages: in the first place, the wine to be distilled is heated without material expense; in the second, the water bath is not obliged to be renewed; in the third, the alcohol is always obtained cold, and all danger of loss or evaporation is avoided.

M. Edward Adam formed successively several large establishments at Cette, Toulon, Perpignan, &c., and secured a patent right to insure the enjoyment of the advantages arising from his inventions; his success, however, very soon awakened the attention of other distillers; his results were such, that they could no longer compete with him, and accordingly they everywhere made attempts either to imitate or vary his process.

The greatest number of the attempts that were made were based upon the fundamental idea, that alcoholic vapor could not be condensed at so low a temperature as steam. The apparatus of Edward Adam was immense and very costly; others sought to reduce the dimensions, and thus to place it within the power of a greater number.

Isaac Bérard of Grand-Gallargues (department of Gard) produced, a short time after, a more simple apparatus than that of Adam, and which obtained the preference over his: instead of covering the boiler with a cap, as had been formerly done, he surmounted it by a cylinder, the interior of which was divided into several compartments communicating with each other by small openings: the vapor arising from the boiling wine was transmitted into these chambers, where the aqueous particles, being condensed, were carried back into the boiler by channels for that purpose, whilst the alcoholic vapor passed into a condensing cylinder which was immersed in a water bath: this cylinder was divided transversely, by plates of copper, into four or five chambers, communicating with each other by openings, so that the vapor might be made either to pass through all of them before entering the worm, or it might be conducted thither after having gone through two or three. The vapor was so far purified in its passage through these chambers, that, when at length condensed in the worm, the alcohol marked from 36° to 38°, (= specific gravity of 0.847 to 0.842,) whilst that which was carried into the worm without going through the chambers, when condensed, marked only from 20° to 25°, (= sp. gr. of 0.935 to 0.906:) all the intermediate degrees were obtained at pleasure according to the number of chambers through which the vapor was made to pass.

The apparatus of Bérard appeared so simple and so advantageous, that it was generally adopted: Edward Adam attacked the author of it as a counterfeiter; the expensive and tedious suits which he was obliged to sustain against Bérard and many others, turned him aside from his business, and this man, to whom we owe nearly all the art of distilling, died almost in poverty, a prey to disappointment and chagrin.

Nearly at the same period M. Cellier, of Blumenthal, conceived the happy idea of economizing time and fuel by multiplying indefinitely the surface of wine submitted to distillation: to effect this, he caused the vapor which escaped from the boiler, to circulate under numerous shallow vessels of copper placed one above the other, and each containing a portion of wine of about an inch in depth. The vessels were constantly supplied with cold wine which flowed from one to the other, allowing the alcohol to evaporate from them; the remainder flowed into the boiler to be again distilled. The liquor, deprived of all its alcohol, escaped continually from the boiler by an outlet in the side.

This process, improved by M. Derosne, is very expeditious, and the expense of fuel when compared with the effects produced, is small.

This method of distilling is called *continual distillation.*

The apparatus of M. Cellier, though protected by a patent, was imitated, and Cellier experienced the same fate as Edward Adam, in consequence of the suits he was obliged to institute against the counterfeiters of his apparatus: so insufficient is the law regarding patent rights.

Since that time distillatory apparatus has received an almost endless variety of alterations; the same general principles, however, prevail in the construction of all of them.*

Some have directed a current of heat, proceeding from a single fire-place, under several boilers arranged side by side: others have varied the number and form of the condensers: several have made arrangements by which the filling of the boilers was facilitated; for ascertainng the time when the liquor no longer contained any alcohol; for heating the wine subjected to distillation without much expense; &c.

These successive discoveries have afforded the means of distilling, in greater perfection than before, the mash of grapes, fermented grains, beer, cider, &c.

By applying to these fermented substances the simple heat of aqueous or alcoholic vapor, the alcohol disengaged is of the best kind, because the liquor, not being exposed immediately to the action of the fire, does not imbibe any empyreumatic flavor; neither is the boiler burned as it is in the distillation of the mash of grapes or grain over the naked fire.

Being obliged either to make choice amongst the kinds of apparatus in general use, or to form a new one com-

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* A work published in two volumes by M. Lenormand is a complete treatise upon the subject, and may be read with advantage.

posed of all the actual improvements which have been successively introduced, I adopted the following.

A boiler capable of holding about 132 gallons of wine is placed over a furnace; to the upper part of the boiler is affixed a pipe, which carries the vapor into a second boiler containing 106 gallons of wine, in which the pipe is immersed about six inches. With the upper part of this second boiler there is connected a tube, which transmits the vapor into a cylinder five feet in length and fifteen inches in diameter; the inside of this cylinder is divided into four chambers, by plates of copper; these chambers or cavities communicate with each other, by small orifices in the upper part of the plates: the cylinder is immersed in a trough of cold water; the water of this trough is renewed at the end farthest from the boilers.

The vapor which is not condensed in passing through the chambers of the cylinder, is carried through a pipe into a worm immersed in the wine, and thence into a lower worm, which is cooled in water. The current of heat, after having heated the first boiler, passes under the second to facilitate the ebullition of the liquid.

Such is the general arrangement of the apparatus; but in order to render the use of it as sure as it is easy, it is necessary to enter into some particulars concerning its construction.

1. In the top of the boiler there is a small pipe with a stop-cock: upon turning the cock a jet of vapor is thrown out, to which a lighted taper is applied; if the vapor takes fire, the distillation is not completed; if the contrary be the case, it is completed.

2. There is, at the lower part of the boiler, a large pipe with a stop-cock for drawing off the residuum or *vinasse.*

3. A lateral stop-cock for ascertaining when the boiler is filled to a sufficient height.

4. A valve, of an inch and a half in diameter, in the top and at some inches from the place where the boiler is contracted; this is used in cleansing or filling the boiler.

At the bottom of each chamber of the condensing cylinder, there should be a pipe to carry off the condensed liquid; these pipes should communicate with a large tube by which the liquor will be conveyed into the bottom of the first boiler; that this may be done with the greatest ease and regularity, it is advisable that a stop-cock be placed in each of the pipes at the distance of about an inch from their insertion into the common tube. As to the upper worm, since the wine which serves it as a bath may become heated to a degree sufficient for producing alcoholic vapor, it is necessary that the cask in which it is contained should be hermetically closed, and that there should be, in the top, only a socket to permit its being filled, and a tube by which the alcoholic vapor may be transmitted to the bottom of the second boiler. A large stop-cock placed laterally at the bottom of the cask serves for drawing off the hot wine whenever the first boiler is to be filled.

The mechanism of this apparatus is easily understood. When the two boilers and the cask containing the worm are filled, the liquid in the first is heated to the boiling point; the second is acted upon by the heat which escapes from the fire of the first. The vapors arising from the first are transmitted to the second, where they are condensed, and give out all their heat to the body of wine into which they pass. This liquid is soon raised to the boiling point, and all the vapor arising from it passes into the condensing cylinder, the coldness of which condenses the aqueous particles, and with them a portion of alcohol. This condensed fluid is returned by pipes into the bottom of the first boiler, where it is deprived of its alcohol by a second distillation. That portion of vapor which remains uncondensed, passes into the first worm, where it is reduced to the liquid state, and this liquid upon passing into the second worm is deprived of all its heat. By this apparatus excellent alcohol, marking from 36° to 38° of the hydrometer, (= specific gravity of 0.847 to 0.837,) may be obtained at a single heating.

As the purity of the alcohol is increased by the coldness of the water in which the condensing cylinder is immersed, it is necessary that this should be changed as often as possible.

It is easily seen, that if the tube which conveys the vapor from the second boiler into the condensing cylinder, transmitted it immediately into the worm, the product would be common brandy; but as it is freed from watery particles by means of the condenser, it yields a spirituous liquor of the higher degrees.

If, instead of filling the first boiler with wine, it be filled with water, and the second with mash of grapes or with fermented grain, the operation may be conducted in the same manner, and alcohol extracted without any hazard of burning the boiler.

This apparatus presents no danger of bursting; the vapor has such free issue from all parts, that the compression is never great enough to occasion an explosion; it is very easily used, and may without difficulty be made to undergo three or four heatings every day, and to furnish from 264 to 290 gallons of good brandy, from wine yielding from $\frac{1}{4}$ to $\frac{1}{5}$.

Neither all kinds of wine, nor fermented liquors generally, yield the same quantity or quality of alcohol: the wines of the south afford more brandy than those of the north; from the first there may be obtained $\frac{1}{3}$; the average is $\frac{1}{4}$; whilst from those of the centre it is $\frac{1}{5}$, and from the north from $\frac{1}{6}$ to $\frac{1}{10}$.

There is great difference in the strength of wines of the same country. Grapes raised in a light, dry soil, and with a southern exposure, yield wine highly charged with alcohol, whilst grapes of the same kind growing in a moist and strong soil, and having a different exposure, furnish wine containing but a small portion of alcohol.

The strength of wine depends upon the quantity of alcohol contained in it, but its quality and its price cannot be calculated in the same way: the odor and taste which render any kind of wine valuable, are qualities entirely independent of the quantity of alcohol it contains.

Wine rich in alcohol is strong and generous, but it has neither the mellowness nor the perfume which characterize some of the other kinds of wine.

The brandy distilled from white wine has a better taste than that from red wine: in the south the red wine is almost everywhere distilled; but the brandy made there, though very abundant, is less esteemed than that procured from the white wine of the west.

Wine which has begun to turn sour furnishes but little brandy, and that of a bad quality; it is therefore necessary that wine which is to be distilled should have been well fermented and kept; and this explains the idea entertained by many distillers, that wine should be distilled as soon as it is completely fermented: this opinion however is unfounded, excepting so far as it regards wine of an inferior quality; strong, generous wine, which has been well fermented, and well clarified, may be distilled at any age.

When wine has been selected for distillation, the process is carried on in the following manner.

The boiler must, in the first place, be carefully washed, or, supposing one distillation to have been previously terminated, the stop-cock must be opened to allow the residuum or *vinasse* to run out: through the valve in the top a stick must be introduced with which the liquid can be stirred, and every thing removed which would tend to form a crust upon the inside of the vessel. The stop-cock may then be closed and water thrown into the boiler; this, after being stirred and allowed to remain some time, is to be drawn off through the stop-cock.

To show the importance of this preliminary operation, it is sufficient to observe, that if it be neglected, the sides of the boiler will become encrusted with tartar and lees, which will speedily give to the alcohol a disagreeable flavor; and which will likewise occasion the burning of the copper, since it cannot be immediately moistened by the liquor.

As soon as the boiler is thoroughly cleansed, it may be filled about three-fourths full of wine; but before pouring the wine in, the side stop-cock must be opened to allow a passage for the air contained in the boiler, which would otherwise throw out the wine, and likewise for ascertaining when the charge is complete: as soon as there is a suitable quantity of wine in the boiler, the fire is kindled.

The progress which the vapor makes through the different parts of the apparatus, is judged of by the heat which they successively acquire, as it passes through them.

The first product is alcohol possessing neither an agreeable odor nor taste, and which is removed to undergo a second distillation. The alcohol which follows this is highly concentrated and of a good quality: the grade of it is determined by the hydrometer, and this instrument is therefore placed at the opening of the receiving vessel, (*bassiot*,) to indicate the strength of the alcohol during the whole time of the operation. For some time the hydrometer indicates nearly the same degree; but as the heat of the apparatus and baths increases, the aqueous particles are less perfectly condensed, and consequently the alcohol, being less concentrated, is inferior in strength.

When the alcohol begins to fall below 20°, (= sp. gr. of 0.935,) the small stop-cock in the top of the boiler is opened from time to time, and a lighted taper is presented to the vapor issuing through it; when this vapor will not take fire, the operation is terminated.

If the same lowness of temperature could be preserved in the water-bath of the condensers, and in the liquid in which the worm is immersed, the product of the whole operation would be of the same specific gravity; the degrees may therefore be raised again when they begin to sink, by changing the baths.

When the operation is completed, the fire is covered, the residuum of the wine removed, and the boiler cleansed and again filled.

Though the alcohol distilled in the course of the operation is not all of the same degree, it may be made so by mixing the several portions; the better way however is to redistil that which is produced last, and thus raise the whole to the highest degree known. There is no need in any case of having recourse to what is called the *water-bath*.

Alcohol should be colorless and destitute of any unpleasant odor; any bad qualities it may have, may be removed by a second distillation carefully performed: indeed it is often enough to filtrate it through well burnt charcoal reduced to a very fine powder. The bad quality of alcohol arises almost always from want of care in the distillation of it, or from a fault in some one or more of the different parts of the apparatus: sometimes, however, it happens th.t it is owing to the wine's having begun to turn sour.

As fast as the vessels which receive the alcohol are full, they are emptied into oaken casks set in a cool place to prevent evaporation: from the casks the liquor acquires a yellowish color, but is unchanged in any other respect. Brandy loses by age the burnt taste which it often has when new, and becomes milder and more agreeable.

The instruments made use of for ascertaining the specific gravity of alcohol, do not give it with mathematical precision, but near enough for commercial purposes: previous to the knowledge of these instruments the methods made use of were very inexact.

The regulation of 1729 ordered powder to be put into a spoon and covered with alcohol; the spoon was then placed over the fire, and the strength of the alcohol was judged of by the kindling or not kindling of the powder. To obtain by this method exact results, it was necessary that the quantity of powder and of alcohol should be always the same; for a larger proportion of spirit would leave, after combustion, a greater quantity of water, and this would prevent the powder from taking fire.

The carbonate of potash has likewise been employed as a test, from its dissolving with more or less ease according to the quantity of water contained in the alcohol.

In the year 1770, the Spanish government ordered oil to be made use of as a test; the process consisted in letting a drop of oil fall upon the alcohol; the strength of the liquor was determined by the depth to which the oil sunk in it. It is evident that this method is very inexact, as the depth to which the oil will sink must depend much upon the size of the drop, and the height from which it is allowed to fall.

In the year 1772, Messrs. Borie and Pouget arrived at some conclusions, which ended in giving to commerce a hydrometer of a sufficient degree of precision to prevent errors of much consequence in estimating the specific gravity of alcohol.

After having made some very exact experiments upon mixtures of pure alcohol with water, and upon the effect of temperature at all possible degrees of concentration, these two learned philosophers adopted an instrument which allows for the variations of temperature. This hydrometer has contributed not a little towards raising the reputation of southern brandy in the north, by furnishing it to commerce of its full strength.

So necessary is the use of a good hydrometer in commerce, that I have seen for more than five years our Languedoc merchants buying Spanish brandy, of which the strength was not uniform, and confining themselves to rendering it of the degree suitable for being sent into the north, and all the other countries where it is consumed.

In the south, where the greater part of the brandy distributed in commerce is manufactured, it is known under different names, which are given to various degrees of rectification. That which marks from 20° to 22° (= specific gravity of 0.935 to 0.923) is called *Holland proof.*

This first quality, when more concentrated, and reduced to $\frac{3}{5}$ by the subtraction of the water contained in it, takes the name of *three five.* When deprived of $\frac{1}{5}$ or $\frac{1}{4}$ more of its aqueous principle, it is known as *three six* and *three seven.*

At Paris, and elsewhere, the hydrometers of Baumé or Cartier are employed for ascertaining the grade of alcohol: these instruments are less exact than that of Borie, but are sufficiently so for commercial purposes.

Alcohol is used as drink; it is employed for dissolving resins, and it enters into the composition of *drying* or *spirit-of-wine varnishes.*

Alcohol serves as a vehicle for the aromatic principle of plants, and then takes the name of the spirit or essence of such or such a plant.

It is made use of by apothecaries for dissolving the resinous gums, and these solutions are known by the name of *tinctures.*

Alcohol forms the basis of all those drinks known by the name of *liqueurs*, which are only alcohol sweetened and flavored with any aromatic substances which will give it an agreeable taste and perfume.

All vegetable substances which have undergone the spirituous fermentation yield alcohol upon distillation, but the quantity and the quality vary much.

Alcohol made from cider has generally a bad taste, because the fermented liquor contains much malic acid, a part of which rises with the alcohol, and remains mixed with it.

Alcohol produced from the fermented liquor of wild cherries is stronger than that distilled from wine, and is known under the name of *kirschwasser.*

Alcohol distilled from fermented sirup of sugar is called *rum* and *tafia.*

Pallas saw, among the Kalmucks and Tartars, the sour milk of cows and mares distilled: the acidification of the milk is facilitated by the addition of leaven, made of coarse salted meal, or with rennet made of the stomachs of lambs: the milk which is destined to be made into brandy is never skimmed. Distillation is performed in boilers covered over with wooden caps, and the product is received into vessels which are cooled by surrounding them with very cold water.

In almost all known countries, brandy is distilled from grains, but it is difficult to obtain it from them free from some bad taste occasioned by the burning of the glutinous fermented matter which adheres to the sides of the boiler, and communicates its flavor to the liquor: this taste is disguised by mixing juniper berries with the fermented grain: the taste of the berries predominates in the liquor, and it is known under the name of juniper brandy or gin.

CHAPTER XVII.

ON THE MEANS OF PREPARING WHOLESOME DRINKS FOR THE USE OF COUNTRY PEOPLE.

A GREAT portion of the inhabitants of the country have no other drink than the water furnished by wells, cisterns, and pools.

The water of wells varies much in quality, according to the nature of the soil through which it filtrates: if that be granitic, or formed by layers of primitive calcareous earth, the water is excellent; when it passes through beds of chalk or gypsum, it is bad: in the first case, the rain-water preserves all its purity; in the second, it dissolves, or carries with it, in a state of extreme division, a portion either of the sulphate or the sub-carbonate of lime. Water of this kind is heavy, very ill adapted to the cooking of leguminous vegetables, or to being used in washing, as it decomposes soap, instead of dissolving it.

The best well-water is liable to be rendered impure by the filtrations of the juices from the dung and from the various substances which are decaying upon the surface of the soil in the vicinity: this evil is often found to exist in the country, where wells and dung heaps are not unfrequently to be seen in the same enclosure, and within a short distance from each other.

I once knew the wells of a whole village to be rendered unwholesome by the rotting of hemp in the ditch which separated the dwellings from the public walk. As the state of the wells was attributed to some want of care, I was requested, by public authority, to ascertain the true cause of it, and found it to be occasioned by the filtration of the water of the ditch into the wells. I caused the ditch and the wells to be thoroughly drained three times, and the water was thus restored to purity.

I have often observed that the use of wells was necessarily discontinued on account of the proximity of a sheep-fold, a stable, or a ditch for manure; the filtrations from them and from the substances decomposing in their neighbourhood rendering the water totally unfit for use. To preserve the water of wells pure, it is therefore necessary, that no animal or vegetable substance which can be decomposed, be deposited near them.

When the water of wells is supplied by living streams, or when the ground around them is paved, or consists of beds of stone or hard clay which will not allow the water to filtrate through, the precautions which I have suggested are not so absolutely necessary; but these circumstances rarely occur in the country.

Cistern-water would be purer and more wholesome than any other, if the roofs, eave-troughs, and basins, could be kept perfectly clean; but the filth deposited by pigeons and other birds upon the roofs, is carried by the rain into the reservoir, and renders it disagreeable to drink, though it is not absolutely unwholesome: this I have observed to be the case upon the most elevated table lands of our mountains, where the inhabitants have no other resource for procuring the water necessary for domestic purposes. I have also observed, when care was taken to cleanse the troughs and reservoirs frequently, and to conduct the first portions of the rains into pools, for the use of the animals, so as to receive only that portion which fell upon the roofs, after they had been well washed, that this water could be kept throughout the year, and that it furnished a drink equally healthy and agreeable.

In most districts, the water of pools forms the only resource for supplying the wants of animals; and when these become dry, during the summer, the animals must often be driven a considerable distance to procure necessary drink. In order, therefore, to prevent the water of pools from filtrating into the ground, and likewise to preserve it sweet, the bottoms of pools should be paved.

In spite, however, of all the precautions which can be taken, it is almost impossible to preserve the water in pools from deterioration: the excrements of animals, and the dirt from their feet, as well as the plants which always spring up in stagnant water, very soon change its color and its nature; it becomes green and thick, and to man, disgusting: fortunately, animals are less delicate, and can accommodate their inclinations very well to drink of this kind: it is even said, that when accustomed to it, they prefer it to the purest and most limpid stream. Such water rarely produces any bad effect; the filth which is mixed with it is slow in decaying, and the plants which spring up, contribute to its healthfulness, and thus we rarely perceive from them that fetid odor which indicates putrefaction. The greatest fault in pond-water, is its temperature in summer, when, from the contact of the atmosphere, it becomes too warm to be an agreeable drink.

It is difficult for country people to go out of their accustomed circle; they employ themselves but little in improving their food, or drink, but take such as nature yields; their drink, however, may, with but little expense, and without much care, be rendered more wholesome and agreeable.

The water made use of is often muddy, or has a bad smell, either of which faults may be corrected, by filtering it through charcoal: the process may be performed in the following manner. Place a large cask upright in the coolest situation you can command, knock out the head, and form, in the bottom of it, a bed of clean sand, upon which place one of charcoal, and above these, fasten securely a double head pierced with holes; when this is done, the cask may be immediately filled with the water which is to be purified: the filtrated fluid may be drawn off by means of a stop-cock, placed at the bottom of the bed of sand: it will be found to have become clear and inodorous in its passage through the sand and charcoal. The preservation of this apparatus requires but little care: when the charcoal ceases to produce the desired effect, it must be either well washed or replaced by a new portion.

When a person is laboring in the fields in summer, the use of warm water as drink, causes him to perspire profusely, by which his strength is reduced. Cold water might always be procured by the use of porous earthen vessels, the surfaces of which would be constantly moistened by the transudation of the fluid through their sides: the continual evaporation produced by the action of the sun's rays upon these vessels, serves to keep the water within them cool. It is by putting water into their *alcarasas*, which they expose to the sun and to currents of air, that the Spaniards contrive to have cool water even in their hottest weather.

Good water is undoubtedly the most wholesome drink; but man has almost everywhere contracted the habit of using fermented liquors, and this habit has created in him a want of them; so that if he be deprived of their use, he loses his strength and energy, and becomes less able to work.

The best fermented drink is wine, but excepting in the wine countries, where the low price of ordinary wine renders the use of it common, the laborer has seldom the means of procuring it daily: it is therefore necessary that its place should elsewhere be supplied by such other liquors as will produce nearly the same effect, and this is done by the fermentation of grains, fruits, milk, the sap of trees, &c., from the product of which there is formed in Europe a great variety of liquors; some of these have become very important articles of consumption and of commerce.

The peasants in the greater part of our districts, have acquired the habit of preparing their liquors from the fermentation of most of these substances; and as the only object I have in view is to furnish information in regard to extending and perfecting these processes, I shall confine myself to pointing out such methods as are easily executed, and which require the employment of such substances only, as are everywhere in the hands of the agriculturist.

All mucilaginous fruits, all fleshy stone fruits, excepting those which yield oil, all grains which contain gluten, sugar, or starch, are capable of undergoing the spirituous or alcoholic fermentation.

The expressed juice of saccharine fruits may be made to ferment by exposure to a sufficient degree of heat. The method most commonly pursued, is that of crushing or grinding the fruits, and thus fermenting the pulp with the juice; in this manner are treated apples, pears, grapes, cherries, &c. &c.

For such fruits as are not very juicy, but contain however some sugar and mucilage, and for such as can be made to keep better by being dried, some water is employed to mix and dissolve the fermentable principles: in this class of fruits may be placed those of the service-tree, the cornelian cherry, the medlar, the mulberry, the privet, the juniper, the Neapolitan medlar, the thorn-apple, the wild plum, &c., and with them the dried fruits of the plum and fig-tree, and of some of the other trees and shrubs before mentioned.

To produce the developement of the saccharine principle in bread corns by germination, they must be moistened with water: the spirituous fermentation is afterwards excited in them by immersing them in water, containing the yeast of beer, or leaven made of wheat flour. The operation of germination may even be suppressed by mixing the meal with a portion of leaven and of luke-warm water; this dough may be allowed to ferment for twenty-four hours, and may then be gradually diluted with water ; fermentation will take place in a few hours, and will go on regularly during two or three days.

As directions for the manufacture of cider, perry, and beer, for general consumption, are much less necessary here, than those for procuring for farmers wholesome liquors at a trifling expense, I shall confine my observations to this object.

Grapes furnish the best liquor, and that in the greatest quantity; but when this is drunk clear, it serves but little purpose for quenching thirst; when made use of in large quantities, it impairs the strength. The liquor called *piquette*, which is manufactured by our farmers, supplies advantageously the place of wine, serving as a tonic, and at the same time quenching thirst.

Piquette is made from the pressed and fermented mash of red grapes, by means of water filtrated through it till it acquires, in some degree, the color and appearance of wine: it is, even in this state, a better drink than water, inasmuch as it is slightly tonic; its good qualities may however be much increased by fermentation.

Piquette can be kept but a short time unchanged, and from this tendency to sour, it is necessary that it should be made only in such quantities as are immediately wanted, and that the manufacture of it should be continued at intervals throughout the year. For this purpose the pressed mash of red grapes is put into a cask, care being taken to crowd it in till the cask is completely full, after which it is hermetically closed so as to exclude air and moisture, and set in a cool, dry place.

When the *piquette* is to be prepared for use, the head is taken out of the cask, and water is thrown upon the mash till the whole mass is moistened with it, and the water stands upon the top: fermentation soon takes place, as becomes evident by the light foam which arises; it is completed at the end of the fourth or fifth day; from this time the liquor may be drawn off for daily use, the place of the portion removed being supplied by an equal quantity of water thrown in upon the top of the mash. In this manner a cask of mash of the capacity of 66 gallons may furnish about 4 gallons of drink per day, and will continue to yield it for about twenty days.

As the mash of white grapes cannot be made to ferment with the juice, this last is separated and put into casks to ferment by itself, and the *piquette* is then made by adding to the mash the necessary quantity of water. This liquor is more spirituous than that made from red grapes, and keeps better; it is therefore reserved for use during the latter part of the summer.

If instead of throwing pure water upon the mash, as is everywhere done, this liquid should first be slightly sweetened and heated, and then receive the addition of a little yeast, *piquette* of a very superior quality would be obtained. In the absence of yeast or leaven, the scum which arises upon wine, especially white wine, during fermentation, may be used for the same purpose; this foam or scum may be dried, and thus preserved for use without undergoing any change.

Well-made *piquette* is a very wholesome drink for country people, from its tonic properties, as well as its power of quenching thirst; it is far preferable, as a daily drink, to wine: but this resource is only local, as in those countries that are most fruitful in grapes, if the harvest fall short, there can be but little *piquette* made; it is necessary then to be able to supply its place from some other source, and this is done by the fermentation of certain fruits.

Apples and pears, as being the fruits that are most abundantly produced, are the most valuable for the purpose of manufacturing liquors: a mixture of the two produces a more wholesome article of drink than does either treated separately. The juice of plums and of other wild fruits may likewise be added, as their astringency renders the liquor more tonic.

Excellent liquor may generally be produced both from apples and pears, by following the well-known method of making cider, which consists in grinding the fruit with a millstone and fermenting the pulp and juice together: but upon farms, where we seldom find the means of preserving liquors unchanged, it is necessary that the processes be simple, and such as can be made use of for preparing them as they are needed; I shall therefore recommend the following method.

Begin to collect the apples and pears which fall from the trees towards the end of August, and continue to do so till they have arrived at maturity; cut them in pieces as fast as they are gathered, and dry them first in the sun, and afterwards in an oven from which the bread has been drawn. If the fruit be well dried in this manner, though it may grow dark-colored, it may be kept unchanged for several years.

When drink is to be prepared from these dried fruits, put about 60 pounds of them into a cask which will contain 66 gallons, fill the cask with water and allow it to remain four or five days, after which draw off the fermented liquor for use.

The liquor thus procured is very agreeable to the taste; when put into bottles, it ferments so as to throw out the corks, as frothing Champagne wine does. Though wholesome and agreeable, it may become still more conducive to health by mixing with the apples and pears $\frac{1}{20}$ of the dried berries of the service-tree, and $\frac{1}{30}$ of juniper berries; from these the liquor acquires a slightly bitter taste, and the flavor of the juniper berries, which is very refreshing, and it is besides rendered tonic and anti-putrescent. The use of this drink is one of the surest means that can be taken by the husbandman for preserving himself from those diseases to which he is liable in autumn, and for the attacks of which he is preparing the way during the greatest heats of summer.

After the spirituous portions of the liquor have been drawn off, very agreeable *piquette* may be made from the pulp which remains in the cask; for this purpose it is only necessary to crush the fruit, which is already soft, and to add to it as much luke-warm water, to which a small quantity of yeast has been added, as will fill the cask: fermentation commences in a short time, and is terminated in three or four days. To flavor this liquor and render it slightly tonic, there may be added to it before fermentation, a handful of vervain, three or four pounds of elder berries and of juniper berries.

Cherries, and particularly the small bitter cherries, when ground and afterwards fermented in a cask in the same manner as the must of grapes, and then pressed to separate the juice from the pulp, furnish a liquor containing much spirit. The wine made from cherries, when distilled, affords an excellent liquor, which although not exactly the same as the good *kirschwasser* of the Black Forest, is yet a valuable drink, and is sold in commerce under the same name.*

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* I know an intelligent landholder, who, without any interruption to his other agricultural occupations, makes every year two or three

The berries of the service-tree dried in an oven and put into a cask, in the proportion of about 16 or 18 pounds of fruit to 26½ gallons of water, furnish, after four or five days' fermentation, a very good drink. Plums and figs dried, either by the sun or in an oven, may be made use of for the same purpose.

In order to render the liquor more wholesome or more agreeable, several kinds may be mixed together, and thus the defects of one kind will be compensated for by the good qualities of another: a few handfuls of the red fruit of the bird-catcher's service-tree counteract the flat, sweetish taste of certain other fruits.

In our farming districts the berries of the juniper are carefully collected and fermented, in the proportion of about 30 lbs. of berries to 38¼ gallons of water: the drink procured from these is one of the most wholesome possible, but it requires a little use to reconcile one to the odor and flavor of it: those, however, who do drink it, prefer it, after a short time, to any other liquor.*

The use of juniper contributes so much to health, that I cannot too strongly recommend its being mixed in greater or less quantities with all fruits which are to be subjected to fermentation: its flavor alone will disguise the taste of such liquors as, without being unwholesome, are flat, sickish, or otherwise unpleasant. The rinds of oranges or lemons, aromatic plants, angelica roots, peach leaves, &c. may likewise be mixed with any of those fruits which are naturally too sweet, and thus serve to raise the flavor of the fermented liquor, and render it more strengthening and efficacious in preventing the attack of disease.

That part of Œnology† of which I treat at this time, is still in its infancy, but I do not doubt that by the application of the true principles of science, and by employing only those products which nature yields us abundantly and without expense, we can procure for the husbandman a

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thousand francs' worth of this liquor: the peasants bring their cherries to him, and he returns them one half of the product of the distillation.

* The fruit of the strawberry-tree, medlar, plum, Neapolitan medlar, thorn-apple, cornelian cherry, privet, &c. may be treated in the same manner, but the liquor made from them is not worth so much as that made from the fruits above mentioned; it is used only by the poorest class of peasants.

[† Œnology, *œnologie* French, from οἶνος, *wine*, and λόγος, *account of*. Science or knowledge of making wine. — Tr.]

variety of drinks more healthy, more agreeable, and better adapted for quenching thirst, than the weak and imperfectly fermented wines made from green grapes.

I have limited myself in this work to pointing out the simplest methods in which such articles as are within the reach of every peasant may be made use of; if such liquors as are more spirituous be wished for, they can be procured by dissolving from 4 to 6 lbs. of the coarsest kind of sugar, in from $5\frac{1}{4}$ to $10\frac{1}{4}$ gallons of warm water, and throwing the solution upon the mash when the cask is filled with it.* To this may be added any number of pounds of raisins.

Liquors suitable for drinking may likewise be manufactured from the sap of several kinds of trees. In Germany, Holland, and some parts of Russia, as soon as the returning warmth of spring begins to cause the ascent of the sap, holes two or three inches deep are bored with a gimlet in the trunks of the birch trees; through the straws which are introduced into the gimlet holes there flows out a clear, sweet juice, which, after having been fermented for a few days, becomes a sprightly liquor, that is drunk by the inhábitants of those countries with much pleasure; it is thought by them to be very serviceable in counteracting affections of the kidneys, stomach, &c. A single tree will furnish a quantity of drink sufficient to last three or four persons a week. The natives of the Coromandel coast fabricate their *calou* from the sap of the cocoa-nut tree. The savages of America prepare their *chica* from the juice of the maize; and the drink of the negroes of Congo is made from the juice of the palm-tree.

It cannot be doubted that the sap of all those trees which afford a saccharine substance can be made to yield a spirituous liquor, but I mention only these few as instances, because our own wants may be abundantly supplied from our fruits and grains.

The fermentation of rye and barley has afforded from time immemorial a liquor, which has supplied the place of wine for the use of the common people in nearly all those countries in which the vine cannot be made to flourish: in those where wine is made abundantly, the use of beer is still very extensive, both on account of the nutritive quality which it possesses in a high degree, and its power of quenching thirst. Though beer may be brewed upon so

* Supposing the cask to contain 66 gallons.

small a scale as to supply the wants of a single family, I shall enter into no explanation of the process, as it requires a degree of care not usually to be found amongst the peasantry, and utensils which they do not possess: I shall confine myself to pointing out some processes by means of which, though they are simple and imperfect, some very wholesome drinks may be obtained from grains.

The sole drink of the common people, and one which is not disdained even by the richest proprietors throughout the vast extent of the Russian territory, is *quass*, and it is there regarded as being nourishing and healthy. We are informed by M. Percy, Surgeon-General of our armies, that the French soldiers who had been accustomed to drinking wine and beer, felt at first some repugnance towards the use of *quass*, but they very soon became accustomed to it, and in the end loved it so much as to manufacture it themselves; they found that it gave them strength and flesh, and preserved them from the attacks of epidemics.

In manufacturing *quass*, one tenth part of the rye to be employed is steeped in water till it becomes soft, it is then spread thinly upon planks in a place warm enough to produce germination, and it is there sprinkled occasionally with warm water. The remainder of the rye, after having been ground, is mixed with the germinated grain, and the whole is diluted with two gallons and a half of boiling water; the vessel is then set into an oven, from which bread has just been drawn, or exposed to an equivalent degree of heat, during twenty-four or thirty hours: if the vessel be put into an oven which it is necessary to heat every day, it may be removed during baking, and returned again after the bread is taken out. After this first operation the fermented substance is diluted by mixing with it 2¼ gallons of water at the temperature of 12° or 15°:* this mixture is stirred for half an hour and then allowed to settle.

As soon as a deposit is formed and the liquor becomes clear, it is thrown into a cask where fermentation takes place; this is completed in a few days, when the cask is removed into a cellar, and the *quass* soon becomes clear. It is in this state that *quass* is drunk by the Russian peasant; but it is much improved by being drawn off into jugs

[* No scale is given; if of the centigrade, equal to from 53° to 59°; if of Réaumur, to from 59° to 65°. — Tr.]

as soon as it has formed its deposit in the cask, and bottled after having been preserved in these vessels till it has become clear.

Quass prepared in this manner has a vinous and sharp flavor which is not unpleasant. The color of it is not very precise, being of a yellowish white.

The imperfections of *quass* might be easily remedied by adding wild apples, or pears, or juniper berries, to the fermented substances. The fermented liquor might be racked off several times from its lees, and clarified by the same process which we use for wine.

The different deposits which are formed during the manufacture of *quass* are entirely of malt, and afford a nourishing and fattening food for animals.

I have found that the operation I have just described for procuring *quass*, might be simplified with the best results by putting the cask in a place of which the temperature was between 18° and 22°.*

I mixed the meal and malt with water at the temperature of 25°, (= 77° or 88¼° Fahr. according to the scale used, — Tr.) so as to form a porridge; this I put the next day into a cask, and added water at a temperature of 20° or 22°, (= 68° or 71° Fahr.;) the liquor was stirred by moving the cask as the water was turned in, so as to mix its contents thoroughly; about one sixth of the capacity of the cask was left unoccupied. The cask was shaken once a day for three days, and after that was left undisturbed; at the end of five or six days fermentation was ended, and nothing more remained to be done than to clarify the liquor according to some of the processes which I have described.

In most of the countries of the north, a drink, which is highly valued by the common people, is prepared by subjecting certain roots to fermentation in unheaded casks, into which they are put, either whole or cut into pieces; the most esteemed is procured from beet roots. These liquors are nutritive, wholesome, and quenching to thirst; but their whitish color and acid taste will for a long time prevent the inhabitants of our fields from making use of them. In countries where wine, *piquette*, beer, cider, &c. are manufactured and sold at a low price, it would not be

[* No scale is given; if upon the centigrade, between 64.4° and 71.8°; if upon Réaumur's, between 72½° and 81½°. — Tr.]

worth while to introduce the use of a new kind of drink, unless it approached, in taste, those already in use, and could be made easily and at a trifling expense. It is for this reason that I have sought to improve the liquor which is procured at a low rate from the various kinds of bread corn.

I put into a vat one hundred weight of rye or barley, and pour upon it a sufficient quantity of water to cover it to the depth of three or four inches; after allowing it to remain four or five hours, I stir it carefully, and by means of a shovel scrape the grain into that part of the vat which is opposite to the opening formed in the lower part and closed with a tap. I then draw out the tap, and allow the water to flow off; and when the grain is well drained, I close the hole and throw into the vat fresh water enough to cover the grain; after two or three days the grain becomes so swollen and softened, that it can be crushed by pressing it gently with the thumb and finger; I then draw off the water, and spread the wet grain upon the pavement or upon planks to germinate; at first it is thrown down in a heap, but when the mass has become heated, which is the case in twenty or four-and-twenty hours, according to the temperature, it is spread in beds of two or three inches in thickness.

Whilst these beds are heating, they must be constantly stirred; and this operation is repeated every six hours, and oftener if heat is developed in the mass.

The first appearance of the radicle is generally perceived as soon as the second day, in the form of a white point at one end of the kernel, and, a short time after, the plumule shows itself at the other extremity. This is the time for arresting germination; and indeed it must be done sooner, if the radicle should become, as it sometimes does, more than a line or a line and a half in length, before the appearance of the plumule.

The beds are spread very thin, and often stirred with a shovel, and, to destroy the germs, are formed either in a place exposed to the rays of the sun, or in one which is sufficiently heated to produce the same effect.

The malt thus prepared is thrown into a vat, and water, heated to the temperature of 40°, (= 104° or 112° Fahr. according to the scale used, whether of the centigrade or Réaumur. — Tr.) is gradually added to it, the grain being stirred and squeezed by the hands, as the water is poured in. This operation is continued till the temperature sinks to 25°; (= either 77° or 88° Fahr. — Tr.) when the malt is converted into a porridge or thin dough; it is then covered over and allowed to remain half an hour. At the end of this time boiling water is poured upon the dough, which is carefully stirred till the heat falls to 50°, (= 122° or 144° Fahr.) The vat is now covered again and kept for three or four hours, after which the covering is removed and the contents stirred till the heat descends to 20°, (= 68° or 77° Fahr.) when the specific gravity of the liquor should equal 7° or 8° of the hydrometer.

In this state a quantity of beer or flour yeast, proportioned to that of the grain employed, is mixed with warm water and turned into the vat, the stirring being still continued. The temperature of the place in which fermentation is carried on should be from 68° to 77° Fahr. Fermentation will be perceived in two hours after the addition of the leaven, and, if the first operations have been well conducted, it will be terminated in two or three days, when the vat must be covered over and the liquor left to settle and become clear: in two days' time it may be put into a cask, and afterwards treated like wine.

This liquor is very wholesome; its color is that of opal, and its taste slightly acid. It can be improved by having the mash of grapes, especially those of the white kinds, fermented in the vat with the grain.

CHAPTER XVIII.

OF FARM BUILDINGS, BOTH FOR MEN AND ANIMALS, AND THE MEANS OF MAKING THEM HEALTHY.

The situation of the first habitations is determined by the vicinity of a river, the proximity of a fountain, or the fertility of a spot of ground. The industry of the inhabitants of these dwellings, and the abundant supply of provisions produced by them, gradually increase their numbers around the same point, and the population soon becomes divided into two classes, of which one is devoted exclusively to the cultivation of the earth, and the other is employed in manufacturing and furnishing to the agriculturist all the implements required in labor.

Rural buildings should be constructed without any reference to luxury: the perfection of them consists in furnishing a healthful abode to the people and animals of the farm, and in storing conveniently and safely the products of the various harvests.

These two requisites in farm building are seldom found united: in one place, men and animals are crowded within damp and badly ventilated places, where they contract innumerable diseases; in another, the harvests are destitute of any protection against the ravages of animals, and the peasant sees the fruit of all his labors devoured before his eyes, without being able to prevent it.

I shall not enter into particulars in regard to the best method of constructing farm buildings: others have written upon this subject, upon which, after all, it is impossible to be very precise, as the necessary arrangements must vary much in different localities, according to the kind of materials that can be procured, the kinds of animals with which a farm is stocked, the nature of the climate, the fortune of the inhabitants, &c.

The art of constructing and arranging the buildings upon a farm in a convenient manner is not the one upon which rural proprietors most need instruction; but that which relates to the salubrity of situation and the means of turning an infected dwelling into a healthful habitation, ought to find a place in this work: to knowledge of this kind the farmer is almost everywhere nearly a stranger.

The choice of a suitable spot for a farm-house is not so easy a thing as may at first be thought: buildings of this kind should always be placed as nearly as possible in the centre of the domain, in order to avoid loss of time and labor in the transportation of the products: the oversight of a farm can likewise be managed more easily by this arrangement.

Independently of these considerations, the buildings should be situated upon the most heathful part of the farm, and where the soil is the least valuable; where there is no stagnant water, and where there is a plentiful supply of pure water, both for drinking and other domestic purposes.

It is often very difficult to find a situation exactly right in all these respects, but the most important consideration, and the one to which all others should be sacrificed, is salubrity.

A farm-house which is built upon a damp soil, or in a narrow spot overlooked by surrounding heights, is always unhealthy; the exhalations which arise from such spots become stagnant, and the inhabitants are continually surrounded by a moist atmosphere loaded with animal emanations, and with those arising from all the substances which are liable to be decaying in the neighbourhood of a dwelling. The greater part of the maladies with which the inhabitants of the country are afflicted, are occasioned by the dampness of their habitations.

When, from the nature of the land and other circumstances, no dry and airy spot can be appropriated for the erection of the necessary buildings, the evil should be lessened as much as possible by attention to certain precautions and arrangements: in all such cases the house or houses designed to lodge the work-people should be built over a cellar, and all should be well aired by means of large doors, windows, and other openings. Nor are these precautions, though of the first consequence, all that is necessary; there are others that it is indispensable to attend to constantly, in order to secure health; amongst these is the digging of ditches to carry off stagnant water and dry the soil, and the transporting to a distance from the habitation, of all such substances as are susceptible of putrefaction.

Constant dampness in a house is destructive not only to health, but to every thing employed in a household, such as provision, clothes, &c.: this cause alone is often enough to ruin a family.

Those who are so unfortunate as to be condemned to live in such places, should employ every means in their power to counteract the evils arising from dampness; they should not remain long, either day or night, in those parts of a building where fires are not constantly made; it would even be useful to burn a little straw occasionally in the middle of the inhabited apartments, as this would serve to purify and change the air.

The greatest degree of cleanliness should be observed in the interior of these habitations; no substance which is liable to be decomposed, should be allowed to remain in them; the walls, planks, and furniture should be carefully rubbed to remove the dampness which they so easily imbibe. With such precautions the unhealthfulness of a house may be much lessened.

The dwellings of animals become even more easily infected than those of men, since no calculation is made as to the extent of ground, or quantity of air that should be allowed them, to admit of their breathing freely, and to prevent their suffering from too great an accumulation of heat. Upon most of our farms they are crowded into badly aired caves, where their excrements are allowed to remain and rot throughout the year, forming a damp and hot atmosphere; and from these infected dens they are not brought out, especially during the winter, excepting to drink. Is it then astonishing that the mortality amongst the animals of our farms should be so great?

Woolly animals do not fear the cold, and the shelter of a shed is sufficient for them in winter: in countries as cold as France and more damp, they are folded in pens nearly through the year.

As cattle constitute the principal riches of a farm, their dwellings should be carefully attended to: the numerous diseases which they suffer from, and especially those that are contagious, and which not unfrequently destroy the whole live stock of a farm, most commonly arise from a neglect of the cleanliness necessary to health, in the stables and sheepfolds. The emanations arising on all sides from the bodies of the animals, mix with the putrid exhalations arising from the decomposing contents of their habitations, and the air is thus loaded with the elements of many maladies: this state of the atmosphere may be prevented by the use of the very simple and efficacious methods employed for rendering prisons and hospitals healthful abodes; the principal of these are as follows.

That the habitations of animals may be healthful, it is necessary that they be spacious enough not only to allow of free respiration, but to permit the inhabitants to assume all the positions natural to them. It is likewise necessary that they should be well ventilated; this may be done by means of windows or doors placed upon opposite sides so as to form a thorough draught of air through; in this way respirable air will be constantly brought in, and the pernicious exhalations as constantly carried off.

It is likewise of great importance that the floors of these dwellings should be paved, and that a slight slope should be given to them, by which all liquid matters may be carried off and conveyed into a reservoir: the pavement should be raised a little above the level of the ground upon the outside of the buildings.

The cribs should be occasionally scrubbed with weak lye, and once a year a coat of lime whitewash should be laid upon the walls.

When the floors of stables and sheep-folds are not paved, the bed of earth of which they are formed should be removed several times in each year and carried into the fields, its place being supplied by a bed of rubbish from salt-petre lands, or by any other dry and porous substance.

Those animals that are accustomed to feeding in the open fields, should not be unnecessarily confined in buildings, as they suffer from weariness, and from the impure air, if detained too long in them. There are but few days in the year when they may not be allowed to come out into the open air for several hours, since even our greatest degree of cold is not injurious to their health, and as soon as the buildings are left vacant, the doors and windows should all be opened to allow of free ventilation.

In some countries no use is made of litter for animals, and in others the litter employed is allowed to remain till it is almost entirely decayed; both of these methods are wrong and contribute equally to render the abodes of animals unwholesome. The litter used should be removed at least as often as once a month; and in the intervals fresh layers should be added as soon as the others become foul upon the top. Where no litter is employed the danger of infection must be avoided by having the floors cleaned every day.

Another and not less pernicious custom is that of forming dung-hills in the corners of stables and sheep-folds, instead of removing the clearings to some other place. By this method cleanliness is secured to a certain extent, but the danger of infection is not removed.

When any contagious disease does make its appearance amongst the animals in the stables or sheep-folds, the first step to be taken is to separate the sick from the well, in order that they may be subjected to different treatment, and to remove the whole to some other spot.

In order to restore the infected building to a state fit for being again inhabited, proceed as follows.

After having removed all the litter, wash the pavement, if there be one, thoroughly; if there be none, scrape the ground so as to remove from it whatever may have been made, by moisture, to penetrate into it. Burn sulphur in all the different parts of the enclosure, so that the vapor may penetrate into every corner; after which whitewash the walls and ceilings with lime, and at the end of several days the animals may return without danger.

The vapor of chlorine (oxigenated muriatic acid) may be employed for fumigation instead of sulphur, it being more active than that: for this purpose, put into a vessel which can bear the fire, two ounces of finely pulverized oxide of manganese, and pour upon it ten ounces of the muriatic acid of commerce; set the vessel over a chafing-dish of burning charcoal, and a vapor of a greenish yellow color will soon appear upon the surface of its contents. This vapor, which is very suffocating, will spread through the whole enclosure and destroy all infection. To make the matter perfectly sure, place vessels of the same kind in the several parts of the enclosure, and thus kindle so many disinfecting fires.

Before the fumigation is begun, the outlets of the building must be carefully closed, in order that the vapor, by being confined, may produce its full effect. The persons having the charge of the heaters must go out into the fresh air as soon as the vapor begins to affect their respiration.

Animals that are crowded together in low, damp places that are not well lighted and aired, often become filthy, and then the moisture and the animal exhalations conspire to render the dwelling an unwholesome one. This evil may be remedied by either of the following methods. Place portions of limestone in several vessels raised a little from the ground; the limestone will absorb moisture from the atmosphere and likewise the carbonic acid given out by the animals, and will consequently fall in pieces and effloresce; this air-slacked lime may be used for whitewashing and other purposes. Or, kindle a strong flame with straw or dry small wood, taking care to watch it well, and to remove the remains of the fire as it ceases to blaze: by this last means the whole internal atmosphere will be changed.

I have employed each of these methods many times, and always with success.

CHAPTER XIX.

ON WASHING, BLEACHING, &C.

Nothing is unimportant to the interests of agriculture which tends to improve the method according to which the daily work of a farm is carried on: this consideration has induced me to treat here of the subject of bleaching.

The object of bleaching is the removal of spots and stains from cloth: those that most frequently occur, are occasioned by oil, grease, or perspiration, and may be removed by soap, clay, or an alkali: those produced by the juices of certain fruits require different processes.

Alkalies can be employed in cleansing fabrics of hemp, flax, or cotton; only those of silk or woollen are destroyed, or at least injured by those substances.

Before entering into the details of the bleaching process, I will mention one common practice which is very injurious to cloth.

When household linen or articles of wearing apparel become soiled, they are usually thrown in a pile in some corner of the dwelling, till a sufficient quantity is collected to form a washing: the consequence is, that the linen, being impregnated with animal moisture, even perhaps so as to be damp, heats and ferments, and the texture of it is thus more injured by lying, than by any use which is made of it as clothing. To obviate this evil, soiled clothing should be hung upon lines in a dry place, so that the articles may neither be heated nor gather moisture.

Washing should never be commenced excepting when the weather is such as to promise three or four fine days. Every housekeeper knows by experience that if she is surprised by rain before her washing is dried, she will lose the greater part of her labor: besides, linen which is put away at all damp, mildews and decays, nor is any thing more injurious to health than the use of imperfectly dried clothing.

If a bad state of the weather should prevent the linen, &c. from being dried in the open air, it should be hung in the barn or around a fire in the house, and not be put away in closets and drawers till thoroughly dry.

The first operation in washing is that of soaking the linen: for this purpose, the several articles must be laid smoothly in a tub, and covered over with a large coarse cloth, upon which water must be poured till the whole is covered with it. The day following a layer of ashes must be placed upon the coarse cloth, so as to be equally thick over the whole surface.* The water is drawn off from the tub by means of a stop-cock placed at the bottom, and is thrown into a boiler under which a fire is kindled: as soon as the water becomes hot, it is thrown upon the bed of ashes, and this operation is repeated for some time; the ley thus formed being allowed to run out of the tub to supply the place, in the boiler, of that which is thrown into the tub.

In this way the linen gradually becomes hot and the ley acquires strength: when the liquid in the copper is near boiling, the operation is discontinued. The linen is allowed to remain in the tub till the ley has done running, after which it is carried to the wash-house.

Nearly all fabrics of hemp require to be bleached, rinsed, and dried, before being used; and as the expense of the soap required would be considerable, its place may be supplied by a soapy liquor that is much less costly: this substitute is formed by putting a quantity of such soda as contains from $\frac{35}{100}$ to $\frac{40}{100}$ of pure alkali, into an earthen jug, with twenty times its weight of water; the jug must be shaken occasionally to hasten the solution, after which it will speedily become clear; this liquor has a slightly saline taste, and should mark 1° (= specific gravity of 1.007) upon the hydrometer of Baumé: when it is to be made use of, a quantity of olive oil † is put into an earthen vessel, and from thirty to forty times its weight of the alkaline solution is poured upon it: by the union of the two fluids there is immediately produced a white liquor of a milky appearance, which, when shaken, froths like a solution of soap. This liquor is put into a bucket and diluted with a little hot water, and the linen is soaked in it, handled, rubbed, and turned, till it is perfectly clean. The ley and oil

* In order to render the ley more active, a little potash or soda is generally added to the ashes; indeed some persons always mix a portion of lime with them, but, unless great care is used, the texture of the cloth will be injured by it.

† The coarsest kind of olive oils, such as are known in commerce under the names of *huiles de fabrique*, *huiles de teintures*, and *huiles d'enfer*, are those which should be employed for this purpose. The finer oils are not so suitable, as they do not dissolve so well in the solution of soda.

need not be mixed, in any greater quantity than is required for use.

When I introduced in the south the method of whitening cotton yarn by the steam from alkaline solutions, I presumed that the same might be used advantageously in washing and bleaching household linen, and experiment has confirmed my opinion.

The apparatus I make use of in this process, is a boiler $2\frac{1}{2}$ feet across at the opening and sixteen inches deep, and having a rim of 1 foot in width around the top: when the boiler is fixed upon the fire-place, there is placed upon its rim, and at the distance of five or six inches from the opening, a tub three feet in diameter and four feet deep, but having no bottom; the brick-work is raised all around the tub a foot from the level of the top of the boiler; this brick-work is so closely united to the tub, that the steam can find no means of escaping. I have frames made five inches less in diameter than the tub, and consisting of cylindrical bars of wood fastened into solid borders at top and bottom, so as to leave spaces an inch wide between the bars: the bars across the bottom of the frame should be stronger than those of the sides.

When this frame is set into the tub, there is an interval of two inches and a half between the two; and the frame rests equally upon the border of the boiler, always leaving sufficient openings through which the steam can circulate.

When this apparatus is made use of, the linen is soaked in a tub containing a solution of soda marking 1° or 2° on the hydrometer, (= specific gravity of 1.007 to 1.014;) it is then arranged upon the frame, care being taken to place those pieces that are most soiled at the bottom and upon the sides.

Three or four pipes made of white iron or copper, pierced with small holes through their length and curved at the end, are placed upon the bottom of the frame at equal distances: the linen must be so arranged upon the frame, that the pipes may be put in as far as the top of the curve, which ought not to be covered with the linen.

As soon as the apparatus is thus prepared, the remainder of the ley, which has been made to boil, may be thrown over the linen; the top of the tub must then be covered over with large coarse cloths, with boards laid upon them. Whilst these arrangements are in completion, the ley with which the linen is wetted drains off and flows into the boiler; as soon as it is seven or eight inches in depth, the fire may be kindled.

The steam arising from the boiling ley spreads itself through the whole mass of linen, penetrating into all its foldings through the openings in the metallic pipes, so that the whole will imbibe a high degree of heat. The boiling of the ley may be continued during three or four hours.

It may be feared that the bottom of the boiler may be burned by being kept dry from the evaporation of the ley; but there is no danger of this, as almost the whole of the steam which arises is condensed and returns again into the boiler. If it be judged necessary to guard against the possibility of this evil, a copper pipe of an inch in diameter may be attached to the bottom of the boiler, and extended to the outside of the wall of the fire-place, and to this may be fitted a glass tube, by means of which the height of the liquor may always be estimated. If by chance it should happen that the evaporation is not sufficiently compensated for by the quantity of condensed fluid returned, the fire can be checked, and a new quantity of boiling ley thrown into the tub.

When the heat has subsided,—that is to say, in eight or ten hours after the fire has been extinguished,—the linen is taken out and carefully washed.

In the year 1802, I had two hundred pair of sheets, which were taken from the Hôtel-Dieu, washed, and was assured by the sisters of l'Hôpital, that they were cleaner and better bleached than by the ordinary process. The expense of the washing, of which an exact account was kept, was less than three sevenths of the expense of the common method.*

When articles made of very fine linen are to be steamed, a solution of soap should be used in preference to one of an alkali.

Cotton yarn can be bleached entirely by the above process. If it should happen that any portion be less white than the rest, a few days' exposure in a field will render it perfectly white.

Messrs. Cadet-de-Vaux and Curandau have exerted themselves much in improving this process, and still more in causing it to be used, both on account of its simplicity

* This apparatus has been established at the *Barrière des Bons Hommes*, in the thread manufactory of the Messrs. Bawens. See the 38th Vol. of the *Annales de Chimie*, page 291.

and its economy. It is now employed in many households, and its advantages are much extolled.

The spots formed by all substances upon clothing, cannot be removed by the application of alkaline solutions. In such cases other agents must be employed.

Cloths of silk or woollen cannot be bleached in the manner here described, as the use of the alkaline solution would weaken or destroy the fabric. It is very important to know the means of removing spots and grease from clothing of all kinds, and the methods to be used must depend upon the nature of the cloths and of the cause of the stain.

The substances by which spots are principally produced are oil, grease, wax, sweat, ink, rust, the juices of red fruits, &c. Scarcely any of these substances, when dropped upon clothing, can be removed by washing alone, even in the hottest water; but each one may be dissolved or evaporated by certain agents. As I write for the inhabitants of the fields, I shall speak only of the simplest of these agents.

A spot of wax may be entirely removed so as to leave no mark, merely by bringing a heated iron so near it as to cause it to melt and evaporate.

Spots produced by any fat substance may be removed by placing the cloth between two pieces of soft brown paper and applying a warm iron, such as is used for ironing, over the upper paper: the oil is liquified and absorbed by the paper. As the fixed oils are volatilized with more difficulty, the operation of freeing cloth from spots produced by them, is completed by the application of such solvents as are suited to the purpose. The alkalies hold the first rank in the class of bodies by which the oils may be dissolved, as they unite with them and form soluble soaps; but the alkalies act upon the oils only when in a nearly caustic state, and for this reason the use of them is confined to a small number of fabrics, and certain other substances, which, though less active, will nevertheless combine with oil, are preferred; amongst these are soap, the white clayey earths, the gall of animals, the yolks of eggs, &c.; these last substances are often mixed and formed into solid bodies designed for the sole purpose of removing grease from garments.

The volatile oils are likewise employed for the same purpose, and they are also used for giving an agreeable perfume to clothing. The *vestimental essences* are composed of these.

Spots occasioned by the juice of fruit may, when recent, be effaced by washing in water; but, when of long standing, this is insufficient, and sulphuric acid or chlorine (oxygenated muriatic acid) is employed. The last of these acids destroys colors, and should therefore be applied only to white fabrics: it is sometimes combined with an alkali, that it may preserve its properties longer; in this state it is known by the name of Javelle water. Sulphuric acid acts much less upon colors, and is therefore preferred for such articles as are dyed or printed.

The spots produced by the oxide of iron are more lasting than those occasioned by the oxide of any other metal. The rust of iron, and some of the combinations of this metal, as that which exists in writing-ink, when deposited upon cloth, become fixed, and form a fast color.

A faint spot of iron rust may be taken out by the application of a weak acid; spots of ink by sulphuric or muriatic acid much diluted; but the best method is that of covering the spot with cream of tartar reduced to a fine powder and then moistening it with water: after having allowed the cream of tartar to remain some time, rub the cloth carefully and rinse it. When an iron-rust spot is of a deep reddish yellow color, these acids are not sufficiently strong, and recourse must be had to oxalic, which may be used in the same manner as the cream of tartar. The place of oxalic acid may be supplied by the *salts of sorrel* of commerce; but the action of the latter is less perfect.

CHAPTER XX.

ON THE CULTIVATION OF WOAD, AND THE EXTRACTION OF INDIGO FROM IT.

For two centuries Woad (*Isatis tinctoria*) has been cultivated in Europe. This plant is biennial, and its hairy and branching stalk rises to the height of three feet. As it is not killed by frost, it affords excellent food for cattle during the winter. It has however been less cultivated for fodder than for yielding the only permanent blue color which was known before the seventeenth century.

The discovery of indigo has greatly checked the cultivation of this plant, and it is now limited to a few localities, where it is used for forming that coloring preparation known under the name of *coques de pastel.* I am, however, much inclined to think that the cultivation of woad may be restored to its former state, and that it will form, sooner or later, one of the most important branches of French agriculture; and this opinion has determined me to devote a chapter of this work particularly to the subject, and I shall treat of it under three heads.

1st. The cultivation of Woad.

2d. The manufacture of the cakes from the leaves of the plant.

3d. The extraction of Indigo from it.

ARTICLE I.

On the Cultivation of Woad.

It appears that the *isatis tinctoria* may be made to flourish everywhere excepting in moist lands; corn-fields and ground which is prepared for cultivation are adapted to its growth; a good crop may be procured upon alluvial soils, but strong soils are preferable, provided they are not too clayey.

The ground in which the seed of the *isatis* is to be sown must be ploughed three times, not only that the ground may be thoroughly softened and divided, but that all the weeds which would injure the growth of the plant, and increase the expense of weeding, may be destroyed. The different ploughings should be performed at intervals of a month or three weeks from each other. In strong lands and those which are disposed to retain too much water, deeper furrows may be traced at certain spaces, so as to form small drains, by which the water that would injure the plant is drawn off. The nature of the manure which is employed in the culture of woad, exerts a powerful influence, not only upon the vegetation of the plant, but upon the quantity and quality of its coloring principle.

The manures which consist of well decomposed animal or vegetable substances are the best, and for this reason night soil, the dung of sheep and doves, the decayed fragments of wool and silk, and the chrysalises of the silk-worm, are preferred to any other manures.

Those substances that act as stimulants to vegetation, such as lime, plaster, marine salt, poudrette, mortar-rubbish, ashes, &c. favor the growth of the plant without affecting the coloring principle.

When land has been dressed with barn-yard manure, it may be made to yield a crop of grain or maize, and afterwards be sown with woad.

The season for sowing the *isatis* varies much in different parts of Europe. In Italy, Corsica, Tuscany, &c. it is sown in the course of the month of November. As it does not receive injury from the cold, it grows during the winter, and in March is sufficiently strong to overcome the weeds which usually make their appearance at that season. From the circumstance of its growing through the winter, it may be rendered a very important article of nourishment for horned cattle.

In the south of France, woad is sown in March, and in England in February. In certain other countries it is sown after the corn harvests; but in this case, a season favorable to vegetation is required, and the practice of sowing at that time can only be followed advantageously in those climates where rains are certain, so that the cultivator may be able to gather two or three harvests of leaves before winter. His fields of woad will afford him pastures for his cattle during the frosts, and he is secure at the return of summer of an abundant harvest of leaves.

The seed of the *isatis* should be soaked in water previously to sowing, as germination will be hastened by it. The seed is sown broadcast, in the same quantity as wheat, and harrowed in. The blade shows itself at the end of ten or twelve days. As soon as the plants have thrown out five or six leaves, they must be carefully weeded, and this must be repeated several times before gathering the leaves. The design of the weeding is to remove all strange plants that may spring up in the same soil, especially the roots of bastard woad, (bourdaigne), the mixture of which injures the coloring matter of the pure *isatis;* and to thin the rows of stalks, that those remaining may have more room to grow.

The *isatis*, like other plants, has its diseases and its enemies. The leaves are frequently seen covered with yellow spots, which turn brown and acquire the appearance of rust: this seems to be occasioned by the sudden changes which sometimes occur in the atmosphere; the rays of a hot sun darting immediately upon plants after a mist or rain, often produces a rustiness of the leaves and stalks.

It often happens, that, in consequence of a great degree of heat accompanied by drought, the plants are not fully developed; the leaves acquire not more than one third of their usual size, yet exhibit all the other characteristics of perfect maturity; the harvest however is lost, for if the leaves be cut in that imperfect state, the plants either perish or languish without yielding any product.

The *isatis* is not exempt from the ravages of insects. there is one called the flea, which often destroys the first and second harvests of leaves; another, known by the name of the louse, attacks the last leaves, but does less injury than the other, because the first harvests are the most important. The snail and the cabbage-worm likewise commit some depredations upon woad.

ARTICLE II.

Preparation of Woad Cakes.

THE manufacturer of woad cakes should avoid cutting the leaves of the plant, till the period when they are richest in indigo; this substance is, to be sure, contained in the leaves of the *isatis*, during all the periods of its vegetation; but the coloring principle does not present itself at all times in the same quantity or of the same quality. In the young leaves the coloring principle is of a delicate blue, in those of a middle age the color is deeper, and in the ripe leaves it approaches to black. It has likewise been proved by observation, that the coloring principle is obtained from the young leaves with more difficulty than it is from those advanced towards maturity.

It appears, then, that the most advantageous time for gathering the leaves of woad, is when they have acquired their full growth. But by what marks is this to be determined?

The manufacturers of woad cakes govern themselves upon this subject according to their own observations, and their modes of procedure vary more or less in different countries.

In England and Germany, the leaves are cut as soon as they begin to droop, and their bluish color to degenerate into a pale green.

In Thuringia, the leaves are gathered when they begin to droop, and to give out a strong, penetrating odor.

In Tuscany, the time for cutting the leaves is judged of by the color which a leaf affords when pressed between two linen cloths.

In the Roman states, the leaves are considered to be matured when they lose the intensity of their color, and begin to fade.

In Piedmont, the leaves are gathered when they begin to fall.

In the south, the leaves are considered as being mature, when they exhibit a violet shade upon their borders.

We are indebted to M. Giobert, of Turin, for an excellent treatise upon woad, in which he states that, according to his observations, the quantity of indigo contained in the leaves of the plant in the most favorable seasons, increases progressively from the eleventh to the sixteenth day of their vegetation, after which time it remains stationary during four or five days, and then begins to decrease. The observations of M. Giobert have been confirmed in the south of France, at Bedford, and in nearly all Italy; and from them may therefore be deduced a general rule, by which the cutting of the leaves of woad may be governed, whenever the vegetation of the plant has been favored by the combined action of a good soil, a warm atmosphere, and a suitable degree of moisture; for without this the leaves will not have reached maturity in twelve or sixteen days, and they should not be gathered before approaching that state.

The extraction of the indigo is uniformly performed with more ease at an earlier period of vegetation, than when the leaves are perfectly mature; the quantity of coloring matter obtained is equally great, and the hue of it is handsomer.

The leaves of the *isatis* are gathered by plucking them off with the hand, or by cutting the stalks with a knife or pair of scissors; but whichever way is practised, care must be taken not to injure the stalks or tops of the plants; the cuttings may be repeated once in six or eight days, so as not to allow time for the quality of the leaves to degenerate. A mixture of the leaves of strange plants, and of the bastard woad, with those of the *isatis tinctoria*, must be carefully avoided.

The leaves, when gathered, are put into baskets and conveyed to the work-shop in which the manufacture of woad cakes is carried on; when they have begun to wither, they are ground between two mill-stones equally channelled; the bruised substance being frequently stirred with a shovel, and the grinding continued till the nerves of the leaves can no longer be perceived by the eye. All the juice which flows out during grinding, is carefully preserved to moisten the paste with when it is fermenting.

The paste is carried under a shed, the ground of which is a little sloping, and paved with cemented stones, in which are little channels for conveying into a reservoir the juice which flows out. Under the highest part of the shed is formed a bed of the paste three or four feet in length; to render this bed as compact as possible, it is beaten down with heavy pieces of wood. Fermentation commences in a short time, the mass swells and cracks, and there flows out from it a black liquor, which is conducted into the reservoir by the channels in the pavement. In some manufactories, this liquor is allowed to run off upon the ground without the shed; but the odor which it diffuses in this case is very offensive.

Whilst fermentation is going on, attention is paid to reuniting the mass when it cracks, and to moistening it either with urine, or with the juice which flowed from it when between the mill-stones.

After the paste has fermented well for three or four days, the mass is again beaten down, and this operation is renewed several times during the twenty or thirty days that the fermentation lasts; the paste being in the intervals moistened with the juice, and the surface of it united.

In a cold season, or when the leaves are poor and dry, fermentation will not be completed in a month; in Italy they often allow four months for it, and sometimes the bed is not removed till the following spring.

There is a kind of worm which often takes possession of these beds, and sometimes in such numbers as to devour all the indigo contained in them; in this case the beds must be turned over, and, if this be not sufficient, the whole must be again ground in the mill.

After fermentation, the paste seldom appears of a uniform texture, and there will be found in it some remains of nerves which are visible to the eye; for this reason it is subjected to a second grinding, after which it is ready to be made into cakes; this is done by filling round wooden moulds with it, or by forming loaves four or five inches in diameter, and eight or ten in height, and usually weighing about three pounds and a quarter. In the south of France the moulds are usually much smaller, and the loaves of woad, known by the name of *shells*, weigh but little more than one pound. These cakes should, when broken, appear of a violet color, and exhale a good odor.

The cakes are placed upon hurdles, and carried to a dry and airy place to harden.

In most countries the cakes are sold in this state to the dyers, who make use of them either to heighten their woad dyes, or for dying by themselves a soft blue; but in general they are made to undergo another process, by which they are improved; this is called *refining*. This last operation is, however, seldom performed by the manufacturers, but by the dealers to whom they are sold in large quantities; the reason of this is, that the process of refining can be performed advantageously only on large masses, and the proprietor of the fields for cultivating woad has only the product of his harvest, and the conveniences necessary for making it into cakes.

For refining the woad cakes, it is necessary that they should either be ground in a mill or broken in pieces with an axe; the fragments are made into beds about four feet high, and sprinkled either with water, or, what is preferable, with the juice of the leaves; heat is developed in a short time, and a violent fermentation takes place. At the end of six days, the bed is turned, so as to bring the interior or under portion upon the top; this is watered in the same manner, and, five or six days after, the bed is again made over with the same care. These operations are renewed at short intervals, till the mass, having ceased to ferment, becomes cold; in this state all the animal and vegetable portions, with the exception of the indigo, are decomposed, and it is now sold to the dyers to the greatest advantage.

The mode of making woad cakes here described, is undoubtedly the most perfect one, but it is not everywhere practised. At Genoa they do not refine them; in the department of Calvados, and upon the Rhine, they pile up the leaves without grinding them; and they mould the cakes as soon as the division of the mass will allow of this operation.

It is necessary to observe, that an immense variety in the quality of the cakes is produced, not only by the nature of the soil and climate, but also by the difference of seasons, and by the care bestowed upon the cultivation of the plant and the gathering of the leaves; and from these circumstances arises the different estimation in which they are held in commerce, and consequently the various prices at which they are sold. The leaves of woad yield about $\frac{1}{3}$ their weight of good cakes; these, when used with indigo to form dyes for producing a permanent blue color, serve not only to facilitate fermentation, but add the indigo which they contain, to that which is brought from India, and thus render the dye less expensive.

The cakes, especially those that have been refined, contain alone a sufficient quantity of indigo to give to cloth all the shades of blue, which can be procured from the imported material. M. Giobert states, that M. Alexander Mazéra, in the presence of several skilful dyers and manufacturers, and of the commissaries of the Academy of Turin, colored with the cakes four pieces of fine cloth of four different shades, and they were judged to be at least equal in brilliancy and durability to those obtained from the best Bengal indigo.

M. de Puymaurin has published an account of a process by which the inhabitants of the island of Corfu color, with the leaves of the *isatis*, the woollen stuffs of which they make their clothing. The practice with them is to cut the leaves when the plant is in flower, and, after carefully drawing out all the nerves, to reduce them to paste in a mortar; this paste is dried in the sun, and when it is to be used for coloring, is placed in a bucket and moistened with water; the mixture gradually heats, and at length ferments strongly; water and a little weak ley of ashes is added, and the paste undergoes the putrid fermentation. Into this composition the cloth which is to be colored is plunged, and allowed to remain eight days, turning it from time to time; in this way it acquires a deep and lasting blue. The ease with which this process is executed, would render it very useful in farmers' families.

ARTICLE III.

The Extraction of Indigo from Woad.

Before the discovery of indigo, the *isatis tinctoria* was cultivated for the manufacture of woad cakes in nearly all parts of Europe: the blue color obtained from this plant was the most durable one known, and the commerce in woad was immense.

The neighbourhood of Toulouse, and particularly Laraguais, furnished an enormous quantity of woad, and the cakes prepared there were everywhere considered of the best quality: this section of the country became so rich, that it was called the *pays de cocagne*, from the name of its manufacture; and this epithet has passed into a proverb, and is used to designate a very rich and fertile country.

Two hundred thousand packages of cakes were exported every year by the port of Bordeaux alone: so great was the want of this commodity amongst foreign nations, that, during the wars we were obliged to sustain, it was always agreed that the commerce in it should be free and protected, and that foreign unarmed vessels should be allowed to come into our ports to obtain it.

The finest establishments at Toulouse have been founded by the manufacturers of woad cakes; when Charles V. wished to secure the ransom of Francis I., who was a prisoner in Spain, he required that the rich Beruni, a manufacturer of this article, should become surety for it.

The indigo, which is an extract from a plant of the same name, first made its appearance in Europe early in the seventeenth century; and the injury which the cultivation of woad would receive from it, was foreseen from the first moment of its introduction. An equal weight of the pure coloring principle of indigo contains about 165 times more coloring matter than the woad cakes do.* Thus 15 lbs. of good indigo, such as is usually employed in dying, are equal, in point of coloring matter, to 2625 lbs. of the woad cakes. From this, some judgment may be formed of the difficulty of producing a deep dye with the woad alone; for, besides the inconvenience of managing

* This calculation is founded upon the supposition that 100 lbs. of woad leaves yield 3 oz. of indigo; for the cakes, which contain all the indigo of the plant, represent only ⅓ of the weight of leaves employed in their manufacture.

such an enormous mass of matter in a dye, the colorer must be very skilful in his art to draw from it a uniform and well-sustained color. It is not then astonishing, that the use of indigo should have superseded that of the cakes, and that consequently the culture of woad should be much diminished.

Henry IV., who foresaw the depreciation of this principal branch of French agriculture, wished to arrest the evil in its infancy, and by an edict of 1609, he pronounced the penalty of death against all those who should make use of "*the false and pernicious drug called indigo.*" The same severity was adopted by the governments of Holland, Germany, and England, though they had not the same interest in the subject: the law was, however, maintained and executed only in the last of these kingdoms.

This source of prosperity may easily be revived in France, not however by increasing the manufacture of woad cakes, of which we cannot extend the use, but by extracting from the leaves of the woad, indigo which shall be equal to that brought from India.

The long war of the revolution deprived us of navigation, and our colonial supplies of various articles became consequently very dear and incomplete: in this state of distress and privation, government made an appeal to our learned men, upon the subject of attempting to obtain from our own soil a portion of the supplies, which had before been brought hither from the New World. The efforts made were not unsuccessful, and in a short time indigo was made from woad, which was not excelled by the best of that brought from Guatimala.

Three large establishments for the manufacture of this article, were established at the expense of government; one at Albi, another in the neighbourhood of Turin, and a third in Tuscany. These establishments prospered for several years, and the processes for obtaining indigo were much improved in them; but the changes which took place in 1813, deprived the manufactories of protection; the establishments were sold by the respective governments, and thus this profitable branch of industry, which would have continued if the establishments had belonged to individuals, has disappeared. M. Roques, a skilful dyer at Albi, has alone maintained an establishment that he had formed, and during ten years he has made use of no other indigo for coloring than that which he prepared himself from woad.

At this time, nothing more is necessary than to make known those simple and advantageous methods by which this branch of manufacturing industry may be conducted. I shall however observe, that it is more profitable to the proprietor to extract the indigo from woad, than to convert the leaves of the plant into cakes.

Hellot assures us that it had been proved in his time, that four pounds of good Guatimala indigo yielded as much coloring matter as a package of Albigense woad cakes weighing two hundred and ten pounds.

At Quiers, in Piedmont, where the dyers are very skilful, it is calculated that three hundred pounds of the cakes afford as much coloring matter as six pounds of the best indigo.*

According to the experiments of M. Giobert, there is no doubt that it is more profitable to extract indigo from the woad leaves, than it is to convert them into cakes.

The indigo which is obtained in America from the *anil*, in Indostan from the *nuricum*, and in Europe from the *isatis*, does not differ sensibly in character: the care which is taken in the manufacturing of it, and the state of the plants, which many circumstances may cause to vary during vegetation, can alone produce some changes in its color, and cause its value in commerce to vary.

This difference in the quality and price of indigo, may arise in some degree from the different methods adopted for extracting it. In America it is made to ferment cold; in Java in the form of a decoction; and generally in India, since the discoveries of the learned Roxburgh, by infusion.

Prior to the year 1810, a great number of processes had been employed in France, Germany, Italy, and England, for obtaining indigo from the *isatis*, without any general method having been established. It was at this period that the French government, urged by the necessity of obtaining a coloring substance which the state of the country would not allow them to import but at a great expense, formed establishments for the extraction of indigo from woad, and offered encouragement to those who would undertake the business.

I shall not describe all the methods that were practised during the three years following 1810. I shall confine

* These results appear to me exaggerated. I place dependence only on those of the experiments which have been made under my own inspection.

myself to pointing out that which is the simplest, least expensive, and most expeditious; and which the most constantly furnishes indigo of a uniform and good quality.

No other apparatus is required in this process, than a boiler for heating water, one tub for leaching, a second for a receiver, and a bucket in which the water charged with indigo is beaten to precipitate the fecula.

The manner of operating, as described by M. Giobert, author of the process, is as follows.

Begin by heating the water till it boils. In the mean time, place the leaves of woad (which have been cut according to the signs of their fitness pointed out in the process for making woad cakes) in the tub, taking care to arrange them so that they shall not be anywhere crowded, and that the distribution shall be equal throughout the whole inside of the tub. Cover the tub with a hurdle of osiers, or with a coarse net, and throw over it a coarse woollen cloth.

When the apparatus is thus arranged, pour boiling water over the leaves till every portion of them be moistened, and the water stand upon the top. Remove the woollen cloth and the net, and stir the leaves gently, that the water may be equally diffused through them, and may not descend to the bottom of the tub, where it will not act upon them.

Allow the leaves to rest during five or six minutes, and then draw off the liquid through the stop-cock of the tub, causing it to pass through a sieve into the receiver. If the color of the liquid be too light, not having the depth of well-charged new white wine, the flow of it must be stopped, and that which has run out is to be again turned upon the leaves, and allowed to remain until it has acquired the appearance just mentioned.

As soon as the liquor is drawn off, turn a fresh quantity of warm water over the leaves, and allow it to act upon them for the space of fifteen minutes. During this second infusion, remove the water of the first leaching into the bucket called the *beater*, and cause that of the second leaching to flow into it, thus mixing the two.

As the leaves are not by these two leachings exhausted of all their indigo, cold water must now be turned upon them; and this may remain an hour or two. The liquor of this third leaching is kept by itself, to be treated with lime-water. After it has been drawn off, the leaves may be strongly pressed, to obtain from them all the juice which may serve to deepen dyes, made of the cakes, for obtaining light blues. M. Pariolati, dyer at Quiers, has found this an excellent article for giving a fine blue to silks. But it can be employed only when the dye-house is in the neighbourhood of the indigo manufactory.

The leaves may also be bruised after having had the two first waters passed through them, and be formed into cakes in the usual manner. These cakes will not be of the first quality, but they are useful as a fermentable substance, and produce in this way the same effect upon the woad dye which is prepared for coloring. This has been proved by experiments conducted upon a large scale, and these cakes are in demand at a price one third less than those made from leaves containing all the indigo.

The process which I have described for obtaining indigo by a hot infusion, is more simple than any other mode. But as the indigo is more or less formed or oxidated in the leaves, according to the period of their vegetation, it is not at all times equally soluble, and especially when it is (as in leaves that have passed their maturity) in the state of blackish blue. It is therefore necessary, when this process is to be followed, that the leaves should be gathered between the sixteenth and eighteenth day of their growth, and before their borders become shaded with blue, as, when that takes place, the indigo has arrived at a degree of oxidation which prevents it from being completely dissolved.

If the method of obtaining indigo by fermentation be less advantageous than the one I have already described, it is capable of being employed upon leaves which have arrived at a higher degree of maturity, and I shall therefore give a short description of it; and I feel the more inclined to do this, because in small manufactories this process is on some accounts preferable to the other.

When indigo is to be obtained by fermentation, a tub is about three fourths filled with woad leaves, pressed down so that they shall remain immersed in the water, which is thrown over them of the temperature of 15° or 16° Réaumur, (= 65° to 68° Fahr.) The heat of the manufactory should be at the same degree. Fermentation will in a short time be evident by the appearance of bubbles, which rise and break upon the surface. This should be terminated in eighteen hours. The period when it should be stopped, may be known by the color of the water being that of a yellow lime, and by the formation, upon the top, of a thin, greenish, and iridescent pellicle. When in this state, the liquor is to be drawn off into the receiving tub, and changed from that into the beating-vessel.

In both methods, it is necessary to precipitate the indigo which is held in solution or in suspension in the water; and this operation, which is called beetling or beating, is needed to give to the indigo the blue color which belongs to it.

There are two methods of beating which are practised, one being applicable to the liquor obtained by infusion, and the other to that procured by fermentation. I shall here describe both of them.

As soon as the heat of the liquor, which has been passed through the leaves in the manner described in the first process, has fallen to between 120° and 111° Fahrenheit, beating is commenced. The instrument employed for this purpose is a broom, or a handful of willow twigs from which the bark has been peeled. With this the liquor is forcibly agitated, the quickness of the motion being gradually lessened as the infusion cools.

As soon as a white foam rises upon the top, beating is suspended, but is resumed again as soon as the foam subsides, and assumes a fine blue color. If the liquor is too hot, or has been too much beaten, the blue borders upon the violet; otherwise it is the color of the sky. Beating is continued at intervals, allowing the foam to exhibit its color. When by rest it appears only of a pale blue, the beating is continued without any interruption. When the foam remains white, or changes to a reddish color, the operation draws to a close.

By beating, the color of the water, which was that of white wine, becomes more and more brown. The beating is ended, when upon pouring the liquor into a glass vessel, it appears of a uniform brown. Should a tinge of bluish green be perceived near the sides of the glass, the beating must be continued. Upon the whole, it is better to beat it too much than too little. The time requisite for performing the operation upon the liquor drawn from three hundred pounds of leaves, is generally about an hour and a half.

When the liquor is at length left undisturbed, the indigo is deposited in grains at the bottom of the bucket. Eight or ten hours are sufficient for this purpose. The liquor is then to be drawn off and the indigo dried, in order that all the water which could cause it to ferment may be separated from it.

In this operation, no foreign substance by which the indigo can be adulterated is employed; and it is therefore obtained as pure as the best of the imported kind.

When the leaves of the *isatis* are operated upon with cold water by maceration, fermentation, or any other method, the indigo cannot possibly be separated by beating. The reason of this is, that the elevation of the temperature is not high enough to cause the combination of oxygen with the indigo, and thus to give it the color and other characteristics which render it so valuable in the art of dyeing.

The substance which in these cases is most usually employed to produce precipitation, is lime-water; but as this process requires much attention, I shall describe particularly the use and action of this ingredient, that the manufacturer may be the better able to direct it.

After all the water which has been prepared in the course of the day, has been collected in a tub, the operation of precipitating the indigo from it is commenced in the following manner.

The liquor is beaten almost uninterruptedly, and without any particular method, for half an hour, the operation being interrupted only to allow the foam to subside and exhibit its color. When the liquor begins to appear of a deep brown, five or six pints of lime-water are thrown into it. The beating is continued, and the lime-water added at intervals, till the liquor exhibits a greenish yellow, begins to grow turbid, and to show in a state of suspension the substance which is about to be precipitated. The quantity of lime-water which is necessary to be used in this process, when added at intervals, in the manner here directed, is never more than one tenth of the volume of the liquor with which it is mixed; but if the lime-water be all thrown in at once, the lime more than saturates the carbonic acid of the liquor, and the carbonate thus formed, being precipitated, mixes with and weakens the indigo.

In the last described method of producing precipitation, a large quantity of air is introduced into the liquor by beating. This combines with the indigo, rendering it insoluble in water, and forming at the same time a great deal of carbonic acid. The admixture of a small quantity of lime-water after each beating, produces an acidulated carbonate, which remains in solution in the liquor, and a kind of soapy combination with the extractive and vegeto-animal portions of the plant, so that the indigo disengaged from its several combinations can be oxidated and precipitated more easily, and in a state of greater purity.

The first result of this process appears to be a much smaller quantity of indigo than is obtained by employing a volume of lime-water equal to that of the liquor. But the indigo obtained is purer, being equal in quality to the kind which bears the highest price in commerce. This process may be employed in all cases; even when the infusion of leaves is at 122° Fahr. The length of time during which beating must be continued in those cases in which it can alone be employed, is much diminished; and yet the indigo obtained is equally as pure.

When all the indigo has been precipitated, the water is drawn off. The precipitated fecula requires some further operations to bring it to the requisite degree of perfection.

The precipitated indigo still contains a greater or less portion of particles which are not sufficiently oxidated, and consequently it has neither the color nor properties which characterize good indigo. Prolonged beating would, it is true, bring these portions to the desired state; but it would likewise cause those particles which had been first oxidated to imbibe an additional quantity of oxygen, by which their color would be too much deepened, and indigo of this quality would be rejected in commerce as burnt; it is therefore better to give to the imperfectly oxidated particles the degree of oxidation required, in the following manner.

Stir the liquid fecula strongly, and throw over the whole mass a volume of warm water, double that of the fecula; by this means the perfect indigo will be precipitated, and the other will be held in suspension by the water. This water is to be drawn off and treated with lime-water, by which the green color becomes of a yellow brown, and the indigo being rendered insoluble is precipitated.

It sometimes happens, that the liquor which has been treated with lime-water, and beaten, if the operations have not been well conducted, still retains a portion of indigo in solution; this can be ascertained by adding lime-water to a small portion of it, to see if it will become brown.

That indigo may have the purity and brilliancy belonging to it, it must be twice washed, once in cold, and once in hot water.

To perform the first washing, collect all the fecula in an earthen pan, and pour over it four or five times its own volume of very pure water; stir the fecula very carefully, raising it with the hand in the water, and let this be repeated occasionally for several hours, after which it may be allowed to settle; when the fecula is entirely deposited, turn off the water and add more, and let this be repeated till the water is no longer colored. As washing in cold water will not remove all the foreign substances which injure indigo, it is necessary to have recourse to hot water; but to perform the last washing economically, it is necessary to collect the product of several cold washings, and to operate upon large quantities.

Before commencing the washing in hot water, the fecula receives a certain degree of consistency by compression, after which it is placed in a tub and allowed to ferment during ten or twelve days, till it exhales a strongly acid odor; by this means a mealy portion, which escapes the action of cold water, is decomposed. The process of washing in hot water is next performed in the same manner as I have directed for the cold washing; the operation may, however, be shortened, and very nearly the same results obtained by boiling the indigo in water, taking care to stir it the whole time.

To bring indigo to the greatest degree of purity, and to give it the forms which it ought to have in commerce, it must undergo certain other processes.

The washings in water remove all those substances which are capable of being dissolved; fermentation decomposes certain principles which are foreign to the nature of indigo; but there still remain in it, in greater or less quantities, certain earths, which, according to their several proportions, adulterate it, and which should therefore be extracted; for this purpose the indigo-paste is thrown into a vat furnished with two or three stop-cocks situated at various heights, and is there diluted with a large quantity of water. The indigo is carefully mixed with the water, so that all the particles of it may swim separately in the liquid; the upper stop-cock is then opened and the water drawn off into a bucket; the second is then opened, and afterwards the third, and the indigo which the water carries off is allowed to precipitate itself.

As the earthy deposit which is formed at the bottom of the vat contains some indigo, it is washed in a great quantity of water, which is drawn off in the same way as the first, this being repeated till no more indigo can be obtained from the deposit.

Nothing more is necessary to be done to the paste of indigo when it has been freed from all foreign substances, than to separate from it the water which renders it of the consistency of porridge; and for this purpose I shall propose a method which I have practised successfully in some analogous operations. Line the inside of a basket with a coarse bag of woollen or tow cloth, throw the paste into the bag, and leave it to drain. When filtration is ended, cover the paste with the upper end of the bag, which had been turned down, and place upon it a large round wooden dish, which will fit the inside of the basket, and upon this put a weight, which is to be gradually increased till the fecula acquires a great degree of closeness of texture: if the operation be well performed, the mass can scarcely be broken by the hand. This cake is afterwards cut into squares, and dried at a temperature of between 30° and 40°. (Probably of Réaumur, and equal to 99° and 122° of Fahrenheit.) The preparation of indigo is afterwards terminated by an operation which is called *sweating*.

M. de Puymaurin states, that the most favorable time for operation is when, "*upon breaking an angle of one of the cubes, a dry noise is heard.*" When this is the case, the cakes of indigo are put into a large barrel till it is full, when the top is covered, without having the head fastened in. The indigo remains in this cask three weeks, during which time it heats and gives out a disagreeable odor, it transpires a portion of water, and becomes covered with a white down. At the end of the specified time the surface of the indigo is rubbed and smoothed, and it is then prepared for sale.

The indigo of woad, if prepared with all the care here described, is equal, if not superior to the best of that brought from Guatimala; its effects are the same in dying, and it differs from that neither in nature nor in characteristics. By the manufacture of this kind of indigo in France, a new source of agricultural prosperity may be bestowed upon her.

It now only remains to be determined whether or not the farmer can with advantage turn his attention to the manufacture of woad-indigo; for without this, though the discovery of the possibility of extracting indigo from the *isatis* would be in itself an important one, it would be of no use to the nation.

If it should be ascertained that this manufacture would be advantageous in peaceful times, it certainly must be regarded as of great importance at those periods, when a maritime war, by increasing the difficulty of procuring foreign indigo, shall cause the price of it in commerce to be greatly enhanced. Besides, if good king Henry IV. was willing to pronounce penalty of death upon the importers of indigo, in order that he might preserve to agriculture the manufacture of woad cakes, why should not government prohibit the importation of the same article as soon as the manufacture of it from woad is established? France would, by such a course, be endowed with a product of the value of at least 20,000,000: she would be placed above the chances of war, would retain within herself an immense sum which passes into foreign hands, and would furnish employment to the numerous population of the fields.

But let us see if, in the actual state of things, the manufacture of woad indigo can compete with the importation of it.

An acre of land (old Paris measure) produces at the various cuttings 7½ tons of woad leaves. At the lowest calculation, the product of an acre in leaves, especially in the south, may be fixed at 7½ tons, and that of the indigo which they will yield, at three ounces per hundred weight, will make nearly 28 lbs. of indigo per acre.

The value of good indigo may be estimated at nine francs (a franc being about eighteen or nineteen cents), and this will make the value of the indigo from an acre of land to be 252 francs. Let us now compare this with the value of wheat raised upon the same land: the quantity of wheat may be estimated at about 12 hectolitres (= 34 bushels), and the price at eighteen francs; this will give 215 francs per acre. We will now calculate and compare the expense attendant upon the cultivation of each plant.

The preparation of the ground by tillage and manures is the same for the seeds of both plants, but the expense of cultivation and of hand-labor differ essentially.

Weeding by the hand is sufficient for wheat, and the expense of this is very trifling, whilst the same operation when performed upon woad, to which it is much more necessary, must be done with instruments which will loosen the earth, and root out all the noxious herbs: the expense of this cannot be estimated at less than twenty-five francs.

The cutting of the leaves, which must be repeated five or six times, amounts during a season to about fifty francs.

The expenses attendant upon the manufacturing processes cannot be estimated at less than two francs per pound of indigo; this will make fifty-six francs.

The seed necessary for sowing an acre costs about twelve francs, but by leaving the roots in the ground to produce seed, this may be reduced to six francs.

Thus, from the gross product, in indigo, of two hundred and fifty-two francs, there must be deducted

	francs.
for weeding	25
" cutting	50
" expense of manufacturing.	56
" seed	6
	137

Deducting this from 252 francs, there will remain a net product of 115 francs, (equal to between $21 and $23.)

The expenses attendant upon cultivating and harvesting wheat are not so great as those for woad; for, stating the price of seed at $\frac{1}{8}$ of the value of the product, and the weeding, reaping, gathering in, and threshing, at $\frac{1}{6}$, the whole expense would be but sixty-three francs, and this reduces the net value of the product to one hundred and sixty-three francs; the balance would thus be in favor of the cultivation of wheat.

It must, however, be remembered, that I stated the value of the product in indigo at the lowest. M. de Puymaurin has obtained five ounces, and that of a good quality, from 1 cwt. of leaves; at this rate an acre of land would yield forty-seven pounds of indigo, instead of twenty-eight; and this sold in commerce even at the low price of six francs, would produce two hundred and eighty-two, instead of two hundred and fifty-two francs. An additional profit likewise arises from the cakes into which the leaves are formed after having been nearly exhausted of their indigo; these may be sold with advantage to the dyers, or if there be no demand of this kind for them, they form a better and more abundant manure than that which is yielded by the dried stalks and leaves of wheat.

I may likewise add, that in those establishments which are in the vicinity of dye-houses, the indigo paste, which produces the same effect as the indigo cakes, may be sold, and thus the manufacturer may save himself the performance of the three principal operations, filtration, drying, and sweating; and the dyer will be spared the trouble of breaking the cakes. I am even assured, that by making use of the fecula, instead of the indigo, which has gone through all the processes, the dyer can diminish the quantity of woad cakes which he uses in the composition of his coloring liquor.

It seems very evident to me that the introduction of this valuable branch of industry into our country, needs only some slight encouragement on the part of government; the only one I would ask is, the augmentation of the present duty upon imported indigo of ten francs per kilogramme, (about 80 cts. per lb.) Without this, the agriculturist can hardly determine to undertake a manufacture, which, though promising advantage, is new to him, and, if badly conducted, presents, like all others, danger of loss.

I shall conclude this chapter by inviting all agriculturists who are zealous for the progress of their art, to undertake the cultivation of the *isatis tinctoria* upon a very small portion of their ground, and in a soil suited to it, for the purpose of making indigo; they may in this way familiarize themselves with the processes of the manufacture so as to be able to enter into it upon a large scale with confidence.

The *isatis* grows and prospers in all climates; that which is raised in the northern departments of our country has been known to yield five ounces per cwt. which corresponds to the quantity afforded by it in the south.

It would be wrong to be discouraged in any undertaking by the failure of a first attempt: neither in cultivation nor in manufacturing can one hope to arrive at perfection at once; time, experience, and especially close observation, can alone enable us to overcome all obstacles, and so to manage our concerns as to be always sure of success. The experiments which I recommend are not costly, neither do they require any other utensils than are to be found in every farm house.

CHAPTER XXI.

ON THE CULTIVATION OF THE BEET ROOT, AND THE EXTRACTION OF SUGAR FROM IT.

I FEEL myself authorized by ten or twelve successive years of experiments and observations upon the cultivation of the beet root, and the extraction of sugar from it, to publish some results which may be relied upon.

As this new branch of industry is capable of being rendered a fruitful source of agricultural prosperity, I shall be pardoned if I enter into all those details which I consider necessary for directing the agriculturist, that he may not try such experiments and commit such mistakes, as often lead to useless expense and are always discouraging.

SECTION I.

ON THE CULTIVATION OF THE BEET ROOT.

BEET SEED is sown in the latter part of April and the beginning of May, when there is no longer any danger of the return of frost. I have sown it with good success towards the middle of the month of June; it is better, however, to sow it neither too early nor too late. If it be sown immediately after the cessation of the frosts, the ground being cold and very wet, the seed does not germinate immediately, and the soil, becoming hardened by the violence of the rains, does not admit the air to penetrate, so that if the seed do not decay, the beets come up badly; when sown late, they suffer from evils of another description; the rains will then be less frequent, but the great heat dries up the ground, and those soils that are rich and compact form a crust, which the tender plumule of the beet cannot pierce. Those seeds which are sown at the right season have to encounter the danger of being stifled by a host of strange plants that spring up with them, and which render weeding very expensive. The most favorable period is that when the earth, although heated by the rays of the sun, still contains sufficient moisture to produce germination, and to facilitate the growth of the young plant: the last days of April and the first fifteen days of May generally unite these advantages.

ARTICLE I.

On the Choice of Seed.

A GOOD agriculturist should always raise his own seeds: for this purpose he will plant his beet roots in the spring in a good soil, and gather the seed in September as fast as it ripens, selecting only the best, and leaving upon the stalks such as are not thoroughly ripe; each beet root will furnish from five to ten ounces of seeds.

When no care is taken in selecting the seeds, and they are sown indiscriminately, not only are many of the beets small, and ill grown, but half of the seeds sown do not yield any thing.

Beets vary in color, some being white, others yellow, red, or marbled; there are even some of which the skins are red and the substance white: it is generally known, that seed from a beet of one color does not always produce the like: a field which is sown with the seeds of yellow beets alone, will invariably yield some roots of the other colors.

Too much importance has hitherto been affixed to the color; I have never myself observed any considerable difference in the products of the different kinds; however, I cultivate from preference the yellow and the white, because the process of refining the sugar made from red beets requires a little more time; for although the lime which is employed in the first operation instantly deprives the juice of color, yet it acquires, during concentration in the boiler, a brownish tinge, which the sirup from white and that from yellow beets does not receive.

ARTICLE II.

On the Choice of Soil.

All corn lands are more or less adapted to the cultivation of beets; but the best soils for the purpose are those that have the greatest depth of vegetable mould.

Sandy soils formed by alluvions and the deposits of rivers are also very favorable to the growth of beets; nor is any other artificial manure necessary upon spots so situated as to receive it, than the mud which is periodically deposited by inundations.

Beets may be cultivated with good success upon natural or artificial grass lands; but I have always observed, that beets came up badly when sown in the spring upon such lands as had been broken up in the autumn, and ploughed two or three times during the winter: the turf and roots do not in so short a time become sufficiently decomposed; and in order to have good beet roots, I find it necessary to raise a crop of oats between the time of breaking up a meadow and sowing it with beet seed: after this I can raise two successive crops of the finest beets. If the soil of a natural grass land is dry, or not closely united, it may be sown with beet seed six months after being broken up; but I have never obtained good harvests of beets from clover lands without having first sown them with a crop of grain: in these lands the beets have always been better the second year than the first.

Dry, calcareous, and light soils are but little suited to the culture of this root.

Strong clayey soils are not well adapted to the cultivation of beets; in order that these roots may prosper, it is necessary that they should grow in a loose, fertile soil, having a bed of vegetable mould of at least twelve or fifteen inches in depth.

Beets prosper to a certain extent in all arable lands, but the quantity as well as quality of the product varies surprisingly with the nature of the soil. Good soil will furnish 100,000 lbs. per hectare, (= 2 acres, 1 rood, 35 perches English;) a poor soil only from 10,000 to 20,000 lbs.

Upon several hectares of lands of very different nature, which I put in cultivation each year, the average rate of production is 40,000 lbs.

The value of beets cannot be calculated by the gross weight; the large roots, which often weigh from ten to twenty pounds, contain a large proportion of water, and the specific gravity of the juice extracted from such will not be more than 5° or 6° of the hydrometer (= 1.036 to 1.044,) whilst that of beets weighing a pound less will rise as high as 8° or 10° (= 1.060 to 1075,) so that the juice of the last contains in the same volume nearly twice as much sugar as does that of the first, and the extraction of it is easier and less expensive, because less time and fuel are required for evaporation. I therefore prefer, in my manufactory, beets which weigh one or two pounds, though the soil upon which I raise them should not yield me more than from 25,000 to 30,000 lbs. per hectare.

ARTICLE III.

On the Preparation of the Soil.

Generally speaking, I cultivate beets upon all such lands as are appropriated for sowing grain upon in the fall. The lands I prepare for receiving the seed by three good tillings, two of which are performed in the winter, and one in the spring: by this last ploughing the dung which is thrown upon the ground after the second, is mixed with it: the quantity of manure employed is the same as if the ground was to be immediately sown with wheat.

When the cultivation of the beet was less known than it is at present, it was thought that the use of dung rendered the root less rich in sugar, and more disposed to produce salt-petre; my own observations have never verified the truth of this opinion, nor have I ever perceived any other difference than that of size between beets raised in ground dressed with barn-yard manure, and those raised in a soil not so prepared. That which has given rise to the error is the greater quantity of sugar contained in the same volume of small beets, in consequence of the more concentrated state of their juices.

ARTICLE IV.

On the Manner of Sowing Beet Seed.

Beet seed may be sown in either of the three following methods. 1. in a seed plot: 2. in drills: 3. broad-cast. The first of these ways offers to the agriculturist the advantage of requiring much the least time at a season of the year when every moment is precious: the young plants may be transplanted in June before the commencement of the hay harvest, so that the cultivation of beets need not in any way impede the ordinary labors of the fields. There are however, some serious inconveniences attendant upon this mode of sowing: the first of these is the care that is requisite in pulling up the young plants so as not to leave behind a portion of the root; for if a tap-root be broken off, it ceases to increase in length, but grows in circumference, and throws out radicles from its surface in every direction. The second difficulty is, that if, in placing the root in the earth, its long and very slender point be bent upward, its growth in length is frustrated in the same manner as if it were broken off. It is however advisable for the farmer to sow a portion of his beet seed in a seed plot, in order that he may be able to fill the vacancies which will always be found in fields sown by the other methods.

But seed may be sown broad-cast in the same manner as grain, and in this case sowing may be commenced as soon as the ground has been well prepared by ploughing and rolling. The seed is covered by having a harrow passed over the ground in two directions, crossing each other. This method requires at least from eleven pounds and a half, to thirteen pounds and a half of seed per hectare.

This last process is the one most generally made use of, and the one which I myself employed during seven or eight years; but I now give the preference to the method of sowing in drills, as being more sure and more economical. For this purpose, as soon as the ground is prepared, I trace upon the surface, by means of a harrow armed with four teeth, distant about eighteen inches from each other, furrows of an inch in depth; the seed is dropped into these furrows at intervals of sixteen inches, by women or girls who follow the harrow, and who cover the earth over the seeds with their hands. Each woman can sow, in this manner, six or eight thousand seeds in a day.

The quantity of seed necessary in this method, is a little less than half what is required for sowing broad-cast, and the weeding of the beets is much easier, and by no means so expensive.

The method of sowing beet seed which has been adopted in England, can scarcely fail of being successful: it consists in opening a deep furrow, in the bottom of which is placed a portion of the manure which is to be used upon the land: a second furrow is then drawn parallel to the first, and so near it that the earth thrown up shall cover that over: the second trench is prepared in the same manner as the first, and so on; the seeds being sown immediately over the manure. By this disposition of the ground the roots easily penetrate through the loose soil to the dung, which retains its moisture, and furnishes the plants with nourishment.

But whatever mode may be followed in sowing beet seed, it is necessary to observe the three following rules: first, to sow only new and naturally fertile soils; second, not to place the seed at the depth of more than an inch; third, not to sow the seeds too thickly.

ARTICLE V.

On the Care required by Beets during their Vegetation.

There are few plants that require more care than beets: their developement is greatly impeded by the neighbourhood of other plants, and if the soil be not light and loose around them, they languish, turn yellow, and cease to grow.

When beet plants begin to show their second leaves, they must be weeded: if they have been sown broad-cast, this can be done only by the hand or with a small hoe or weeding fork; all the weeds must be rooted up, and as many of the plants removed as will leave spaces of eighteen inches between those that remain. If the plants are sown in furrows, the plough may be passed between the rows, and the roots of the plants be cleared with the weeding fork. The same operation must be repeated at least twice in a season.

As weeding opens the earth to the free entrance of air and water, the plants may be seen to be benefited by it; the green of their leaves deepens, their roots increase in size, and their foliage expands.

Since I have sown my fields in drills, I have practised passing the plough through them three times in the course of a summer, and at each time I have made thorough use of the weeding-fork around the roots of the plants.

Half a day's use of the plough is sufficient for half a hectare, and the rest may be completed in a day by five or six men. I find that I save one half the expense of weeding by employing this method. Each weeding with the fork costs at least twenty francs per acre. The produce of a field which is well taken care of, is at least double that of one which is neglected.

ARTICLE VI.

On the Gathering of Beet Roots.

Beet roots are generally dug during the month of October: the digging should be completed before the commencement of the frosts. When surprised by untimely frosts, if the roots cannot readily be transported to a place of shelter, they may be collected in heaps upon the fields and covered over with their own leaves: those that remain in the earth are in much less danger from frost than those that have been dug.

The time mentioned in the preceding paragraph is the one most suitable for the vicinity of Paris, and for the centre of France; but as vegetation is more forward in the southern departments, it is necessary that beets should there be gathered earlier in the season, otherwise the saccharine principle may disappear, in consequence of a new elaboration of the juices after maturity The fact appears to me to have been fully ascertained by the experiments of M. Darracq. This able chymist, in concert with the Count Dangos, Prefect of the Department of Landes, made every arrangement for the establishment of a sugar manufactory.

During the months of July and August, he made experiments upon beets every eight days, and always obtained from three and a half to four per cent. of good sugar. Satisfied with these results, he discontinued his experiments, in order to devote all his time to the care of his establishment; but how great was his surprise at finding towards the end of October that his beets yielded only sirup and salt-petre, and not a particle of crystallizable sugar.

Generally speaking, beets may be dug as soon as their largest leaves begin to turn yellow. If harvested before arriving at maturity, they wither, wrinkle, and grow soft: the juice is extracted from them in this state with more difficulty, and the sugar does not grain so well.

The leaves, which are separated from the roots as fast as they are taken from the ground, may be left upon the spot and there eaten by cows, sheep, or swine; but they are so abundant that there will still remain enough to serve as a half manure for the land, and it is in this soil, after having slightly ploughed it, that I sow my grains. As the earth has been manured in the spring, and afterwards freed from weeds by repeated hoeings, the corn will grow very large and be very clean; so that the first tillage and manuring serve for two harvests, and the ploughings which are given in autumn to lands appropriated to the reception of wheat or rye, are saved.

ARTICLE VII.

On the best Method of Keeping Beet Roots.

Beets are affected both by cold and heat: they freeze at a temperature one degree below the freezing point of water, and they germinate with a degree of heat but little above freezing: freezing softens them and destroys their saccharine principle, and they decay as soon as they are thawed. Heat developes the stalks at the necks of the roots, and decomposes the juices which supply their growth. During the first stages of germination, the alteration of the juices is only local: so that if the neck of the root be cut off, the remainder of it may be made use of without any inconvenience. In order to keep beets, it is necessary to preserve them both from heat and cold.

The first care of the farmer must be, to have his beets thoroughly dry before being housed. The best way is to leave them in the fields till all their dampness has evaporated. When, however, a large harvest is to be gathered in autumn, a sufficient number of fine days to effect this can hardly be hoped for, and the roots must therefore be stored for the winter in such a manner as will be most likely to prevent decomposition.

I have an immense barn, where I pile up my beets to the height of seven or eight feet, as fast as they are carried from the fields. I make use of no other precaution than that of forming against the surrounding walls a layer of straw or broom, which rises as high as the pile of roots; when the frosts set in, I cover the pile over with straw; and in this way I have for ten years preserved my crops of beets uninjured by them. It has, however, happened two or three times, that the roots began to germinate with so much energy, that I was fearful they would become decomposed. In these cases, I unstacked and spread the beets, and thus arrested the process of vegetation.

Some farmers leave their beets in the field. In order to preserve them, they dig a trench in a dry soil, giving the bottom a gentle slope, that water may flow off easily. This trench they fill with the roots, and cover it over with a bed of earth a foot thick; upon this they throw heath or broom, to prevent the rain from penetrating. Some line the bottom and sides of the trench with straw or heath.

Instead of being put into trenches, the digging of which is always expensive, the beets may be preserved in the fields by forming heaps of them upon a dry soil, and covering the tops and sides with layers of earth; or they may be covered over with a roof like the one I have heretofore described. This method of preserving roots may be employed when there is no suitable storehouse for them; or when the means of conveying them to one in autumn are wanting.

SECTION II.

On the Extraction of Sugar from Beets.

I shall not here describe the numerous difficulties that have been encountered before arriving at sure methods and certain results. I shall confine myself to the description of the simplest and most advantageous processes that are employed at this time; and I will draw my examples from my own practice, enlightened as it is by twelve years of experiment and observation. I have successively executed all the known processes; I have tried all the improvements that have been suggested; I have myself regulated and improved some of the processes; and I shall describe only such as I have proved and confirmed.

ARTICLE I

On the Preparation of the Roots.

Before subjecting the beets to the teeth of the rasp, they must be carefully freed from all the earth which they bring with them from the fields. The necks, and any portion that has begun to decay, must be cut off, and the radicles removed from the surface.

In many manufactories, nothing more is done to the roots than to wash them. But this operation cannot be conveniently practised in all places, and I have therefore dispensed with it as a preliminary; nor have I found any bad effect to arise from the omission of it. Eight women can easily prepare 10,000 lbs. of the roots in a day. If the beets are large, and retain but little earth about them, the same number of women can prepare in the same time from 15 to 20,000 lbs.

ARTICLE II.

On the Method of Rasping the Beet Roots

THE beets, when well cleansed, are submitted to the action of a rasp, by which their fibrous substance is reduced to a pulp. The rasp is worked either by a horse, or by a stream of water. The rapidity of its motion should be equal to four hundred revolutions upon its axis in a minute.

The rasps used by me, are sheet-iron cylinders, fifteen inches in length, and twenty-four in diameter, having their surfaces furnished with ninety iron plates armed with saw teeth, and fixed by screws perpendicularly to the axis of the cylinder and throughout the whole length of it.

The beets being pressed against the rasp, by means of a piece of wood held in the hand, are immediately torn in pieces. The pulp falls into a box lined with lead, which is placed beneath. The table upon which the beets destined to the rasp are placed, is so near the instrument as to allow only sufficient space between for the passage of the pulp.

The operation of rasping must be conducted expeditiously, otherwise the pulp begins to turn brown, fermentation takes place, and the extraction of the sugar is rendered difficult. By the use of two rasps, put in motion by the same horse, I have reduced 5000 pounds of beets to a pulp in two hours. The pulp should not contain any portion of roots that have not been acted upon by the instrument.

Compression will not in any degree supply the place of rasping. The strongest presses can never extract from beets more than from $\frac{40}{100}$ to $\frac{50}{100}$ of their juice, whilst the pulp, if properly managed, will yield from $\frac{75}{100}$ to $\frac{80}{100}$.

ARTICLE III.

On the Extraction of the Juice.

As fast as the pulp falls into the box placed under the rasps, it is put into small bags made of very strong cloth woven of pack-thread. These bags are placed upon the plate of a good iron screw press, and submitted to a strong pressure. The screws are after a time to be loosened, the places of the sacks changed, the pulp which they contain shaken over, and the whole again submitted to the action of the screw.

Sometimes the pulp is first acted upon by a cylindrical press, by which about $\frac{60}{100}$ of its juice is extracted, and the operation is afterwards completed by means of the screw press. But 10,000 pounds of beets may be pressed in a day by the last alone.

The pressure should be continued till the pulp will not moisten the hand when strongly squeezed in it. The juice which flows from the press, is carried by leaden pipes into the boiler, where it undergoes the first operation. Of this I shall speak immediately.

If an iron screw press is not to be had, a wine press, a lever press, or a cylinder press will answer the purpose.

The operation of the press should be completed nearly at the same time with that of the rasp. Every thing that has been moistened with the juice, must then be washed so as to be ready for a new operation. The utmost cleanliness must be preserved, otherwise the rasps will become rusty, the juice will change, and the boiling will be rendered difficult.

The juice extracted from beets, is not always of the same degree of concentration. It varies from 5° to 10°, (= specific gravity of 1.036 to 1.075,) according to the size of the roots, the nature of the soil in which they grew, and the state of the atmosphere during vegetation.

The juice of the large roots is less concentrated than that of the small ones. The juice of such as grow in a light soil, and have been exposed to heat and drought, marks 11°, (= specific gravity of 1.083;) but there is but little of it. The greater the specific gravity of the juice is, the greater is the proportion of sugar contained in it; and, of course, the greater is the saving of labor in the extraction of the sugar.

ARTICLE IV.

On the Purification of the Juice.

As soon as the boiler which receives the juice is one third full, the fire is kindled; and, as the juice continues to flow, the heat is raised to 65° of Réaumur,* (= $180\frac{3}{4}$° of Fahrenheit.) Whilst the juice is heating, some milk of lime is prepared, by pouring gradually some warm water into a bucket containing ten pounds of lime.†

As soon as all the juice has passed into the boiler, and become heated to the degree mentioned in the last paragraph, the milk of lime is thrown into it, the greatest care being taken to stir and mix them well together; after which the temperature may be raised to the boiling point. As soon as the first bubble makes its appearance through the thick glutinous scum which rises upon the top of the liquor, the fire is immediately extinguished by throwing a pailful of water into the fire-place. The scum thickens, dries, and hardens by rest. The juice becomes clear, and takes a light yellow hue. When there can no longer be seen in it particles either of lime or mucilage, the scum is removed with a skimmer and thrown into a bucket, in order that the juice which it contains may be expressed. The upper stop-cock is then opened, and the liquor is suffered to flow into the evaporating boiler.

The juice does not become clear in less than an hour, and evaporation ought not to be commenced till it is perfectly limpid.

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* I have worked 10,000 pounds of beet roots per day, at two operations of 5,000 pounds each. The first began at 4 o'clock, A. M., and the other at noon. The round boiler, which received the juice of one operation, was five feet and six inches in diameter, and three feet eight inches in depth. I had a separate boiler for each operation, and each boiler had two stop-cocks, one close to the bottom and the other five inches above. Between these two boilers, there were two vessels fifteen inches deep, and each of sufficient capacity to receive all the juice of an operation. In these, evaporation is carried on. The rims of all these boilers should be very wide, so as to cover the thickness of the wall in which they are set.

My rasps and presses are placed upon the first floor, in order that the juice may flow through leaden pipes into the boilers, which are upon the ground floor, and thus save the labor of transportation. By this arrangement, I can have my depuratory boilers so much raised, that, upon turning the stop-cocks, the juice will flow into the evaporating vessels.

† My boiler contains $475\frac{1}{2}$ gallons of juice; so that I employ the lime in the proportion of about 46 grains, troy.

As soon as all liquor above the level of the upper stop-cock has passed out, the second stop-cock is turned; and if the liquor flowing through that be found clear, it is mixed with the first portion. If, on the contrary, it appears cloudy, the stop-cock is again closed to give it time to settle, and it is not made use of till towards the termination of the evaporation.

The deposit which is formed at the bottom of the boiler, renders the last portion of the juice turbid. But as soon as this is seen to be the case, that which remains is drawn off into the bucket containing the scum.

The deposit which is formed at the bottom of the boiler, and this scum, are expressed by means of a lever press of very simple and cheap construction, and which is very easily worked.

I place a cylindrical willow basket upon a block of stone three feet square, the upper surface of which is slightly inclined and furrowed with channels an inch deep, uniting in a common centre at the lowest angle. The basket is lined with a bag of coarse cloth, the end of which turns back and hangs down. Into this bag I put the deposit and scum; then, drawing the edges of it together, I tie the mouth closely with a pack-thread. I place on the top a wooden trencher of the diameter of the inside of the basket. This I load with several square pieces of wood, which project over the upper part and serve as a fulcrum for the lever. When things are thus far arranged, I proceed to adjust the lever, which is five feet long. This is fixed at one end to a ring-bolt which passes through a stone. The other end I load with weights to the amount of from 56 to 112 pounds, increasing them at pleasure, so as to produce a gradual and constantly increasing pressure, which may be rendered as powerful as is necessary. The juice which is thus forced out, flows into a bucket and is thrown into the evaporating vessel.

The most difficult operation to be performed, is that of purifying the juice; and if this be not thoroughly done, the processes of evaporation and graining are long and troublesome: the juice swells and bubbles up in the boiler, and the sugar crystallizes imperfectly and remains mixed with molasses. The lime which is thrown in to clarify the juice does not always rise to the top with the scum, by a prolonged period of rest in the depuratory boiler; neither is it always precipitated. It sometimes happens, that, notwithstanding all the care that can be taken, the liquor remains cloudy ; and in such cases it is always in vain to look for good results. I have endeavoured to ascertain the cause of these accidents, and I have sought to remedy the evil. I shall report here only what appears to me to be fully established by experiment and observation.

The juice does not purify well if the beets have begun to germinate too strongly, or if they have begun to decay, or have been frozen.

When the operations of the rasps and presses are conducted too slowly, so that the juice stands five or six hours before being purified, decomposition commences, and good results are never obtained.

If all the utensils employed are not carefully washed after each operation, so as to free them thoroughly from the juice adhering to them, the labor becomes difficult and unsuccessful.

I found, upon one occasion, that beets which had been kept in a cellar, where they had neither frozen nor germinated, did not, when subjected to experiment in March, yield sugar. They appeared perfectly healthy, though a little softer than those that had been kept in barns.

If the first operations are not well conducted, the results are always bad. I can only point out the steps that can be taken to prevent this.

Beets that have been well kept, may be worked with equally good success from the beginning of October to the end of March.

When the juice does not become clear, a small quantity of sulphuric acid may be thrown into the evaporating vessel, a little before the liquor begins to boil. This will remedy any trouble arising from the use of too large a quantity of lime. It will, however, be useless, if the faults proceed from an altered state of the beet juice.

By making use of a portion of animal charcoal to clarify the liquor, the evaporation of the juice and the graining of the sugar is sure to be rendered more easy ; but the quantity of sugar obtained is very small.

The lime used in the process of purification combines with the mucilaginous principle of the beets, and neutralizes the malic acid contained in them ; after this operation, the juice weighs 1° or 1.5° less than before.

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ARTICLE V.

On the Concentration or Evaporation of the Purified Juice.

As soon as the bottom of the evaporating vessel is covered with juice, the fire is kindled, and ebullition is produced as speedily as possible, — the juice which continues to flow from the clarifying boiler supplying the loss occasioned by evaporation.

When the boiling juice marks 5° or 6° (= 1.036 to 1.044) of concentration, a portion of animal charcoal is thrown in, and this is continued, the quantity being gradually increased, till the juice is concentrated to 20°, (= 1.161.) Sixty pounds of charcoal are used in this manner, for a quantity of juice equal to from 422 to 475 gallons.

After having brought the liquor to the twentieth degree of concentration, the boiling is continued till the sirup marks 27° or 28° of the hydrometer, (= specific gravity of 1.231 to 1.242.) The sirup, being mixed with animal charcoal, requires to be filtrated. This operation, as it is usually performed, is very tedious, and sometimes becomes impracticable; the consistency of the sirup is increased two or three degrees by cooling, and the pores of the filter becoming, in a short time, obstructed by the finely divided charcoal, the thickened liquor can no longer pass through them.

To obviate these inconveniences I place a large willow basket over a boiler; into the basket I put a coarse bag of the same diameter, but about two feet deeper. I pour the thickened sirup into the bag; for some minutes filtration goes on very well, but as the liquor grows thick in consequence of its cooling, filtration slackens and at length stops; as soon as I perceive this, I turn the borders of the sack into the basket, and upon them place a wooden trencher, which I gradually load with cast-iron weights till the necessary pressure is produced; filtration is by this means completed in two or three hours.

The charcoal contained in the sack is leached with warm water, and afterwards submitted to the lever press, to force from it all the sirup contained in it. The waters used for these leachings during one day, are the next day mixed in the clarifying boiler with the juices that are then prepared.

The conversion of the juice into sirup should be done as speedily as possible; for when evaporation is slow the liquor becomes pasty, as part of the sugar is decomposed and passes to the state of molasses, and the difficulty of boiling is increased. It is necessary then that evaporation should be carried on with violent boiling, and for this reason the boilers made use of should be broad and shallow, so as not to heat only layers of the liquor, and in order that ebullition may take place at once through the whole mass of the liquid; the furnaces likewise should be so built as to heat the boilers equally. The evaporation of 422 gallons should be completed in four hours.

The operation is known to be good, and the juice to have been well prepared, when ebullition takes place without causing the liquor to swell and blister; when there appears on the surface only a brownish foam, the bubbles of which disappear immediately upon being pressed with a spoon, and when a dry sound is produced by striking upon the liquor.

If, on the contrary, there forms a whitish, gluey foam, which does not subside, the operation is bad; evaporation requires a long time, and the boiling is difficult. In this case a little butter is, from time to time, thrown upon the surface to quiet the effervescence; the quantity of animal charcoal is increased, and the fire is checked. All these palliatives, however, do not correct the radical fault, and such appearances always presage bad results.

ARTICLE VI.

On Boiling the Sirup.

The sirups prepared over night are the next day dried to extract the sugar from them.

The products of two operations upon 5000 beets are mixed together in a boiler, whence they are taken to form four successive dryings or boilings. One fourth part of these sirups is thrown into a round boiler, forty inches in diameter and twenty in depth; under this a fire is kindled; the liquor is made to boil, and the boiling continued till the operation is ended.

The process is judged to be going on well if the liquor exhibits the following symptoms.

1. When the sirup breaks short, and the bubbles upon returning into it produce a sensible sound.

2. When a dry sound, like that produced by striking silk, is returned from the surface of the sirup when it is struck with a skimmer.

3. When the bubbles of foam disappear immediately upon being pressed with a spoon. The boiling is always perfect when the interior surface of the boiler is found, after the operation is ended, to retain no trace of blackness.

The sirup is known to be bad by the following signs:

1. When a thick, whitish, gluey foam appears upon the surface of the liquor.

2. When the liquor swells and foams, and does not subside.

3. When the escape of puffs of acid steam announces that the boiling substance is burnt.

The evils are palliated and the boiling terminated,

1. By removing the foam as fast as it forms.

2. By throwing into the substance small pieces of butter.

3. By stirring the liquor with a large spatula.

4. By mixing with it a little animal charcoal.

5. By moderating the heat.

To avoid a portion of these evils, I throw a flood of sirup into the boiler, and remove the whitish foam that arises; I stir the sirup strongly three or four times before boiling commences, and skim it each time. The scum that is removed is thrown into a bucket with that which is produced during all the time that the liquor is boiling; these skimmings are afterwards subjected to the lever press, and the remainder washed, to obtain from it all the juice contained in it. The sirup obtained by pressing upon one day, is added to the liquor that is boiled the next, and the water of the leaching is thrown into the evaporating boiler.

When the sirup in the drying vessel shows itself to be bad, especially when it gives out puffs of sharp steam, which declare the substance to be burnt, it is necessary to arrest the process and to treat the sirup with an additional portion of animal charcoal. In this case the liquor is diluted with water till it falls to 18° or 20° of concentration, (= specific gravity of 1.143 to 1.161,) and then the charcoal is added; after which ebullition is renewed till the sirup rises to 28°, (= 1.242,) when it is filtered and dried. I have found this to be the only way in which I could restore a sirup which had been injured in the process.

I have myself made particular observations upon the thick, whitish, unctuous and paste-like substance, which is almost always found upon the sirup, and which, when it is abundant, prevents the drying from being well-terminated. This substance renders the sirup ropy, adheres to the sides of the boiler, which are blackened by it, separates itself from the sirup, in proportion to its concentration, and prevents the object proposed from being attained.

I have noticed that the quantity of this substance was in proportion to the germination of the roots, and that it was increased by the incomplete purification of the sirup, and also by a slow evaporation. Animal charcoal produces an astonishing effect in lessening the quantity of it; sometimes, if well employed, the formation of it is prevented, or that which is produced is made to disappear.

This substance, which, during the first years of my establishment, I often collected in large quantities, is thickened and hardened by cold; it is insoluble in water or alcohol; it burns with a white and inodorous flame; and possesses all the characteristics of vegetable wax, from which it is in no wise different.

The drying is ended when the boiling sirup marks 44° or 45°, (= specific gravity of 1.440 to 1.454.) The time for removing the sirup from the boiler may be known by the following signs.

1. Plunge a skimmer into the boiling sirup, and upon withdrawing it pass the thumb of the right hand over its surface; mould the sirup which adheres to the thumb between that and the fore finger, till the temperature be the same as that of the skin; then separate the thumb and finger suddenly; if the boiling be not completed, no thread will be formed between the two; if there be a filament, the boiling is well advanced; and the process is completed as soon as the filament breaks short, and the upper part, having the semi-transparency of horn, curls itself into a spiral. This manner of trying the sirup is known by the name *proving*.

2. The second mode of judging of the completion of the process, is by observing the time when the sirup ceases

to moisten the sides of the boiler, and then blowing forcibly into a skimmer which has just been immersed in it; if bubbles escape through the holes of the skimmer which ascend into the air in the same manner as soap bubbles do, the liquor is considered to be sufficiently boiled; the fire is therefore immediately extinguished, and the sirup is a few minutes after conveyed to a great copper boiler, which is called the *cooler*.

The cooler is placed in an apartment of the manufactory near the boilers; its capacity should be such as to allow of its receiving the product of the four successive boilings. The cooling which the sirup experiences in this vessel, quickly produces crystallization; the crystals form first at the bottom, where they collect in a thick bed, having, however, no union of particles. Gradually the sides become covered with solid crystals, and at length there is formed upon the surface a crust of sugar which thickens insensibly. At this time the contents of the cooler are taken out to fill the moulds in which the process of crystallization is to be completed.*

The contents of the cooler are first thoroughly stirred and mixed, and then thrown gradually into the moulds, a portion being put into each in turn, so as to fill them all equally: an interval of an inch is left between the surface of the sirup and the top of the mould.

Crystallization is hastened by carrying the moulds, as soon as they are full, into the coolest apartment of the manufactory.†

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* The moulds used in this operation are known in refineries by the name of *grandes bâtardes*. They are large conical vessels of baked earth, with a small opening at the apex, and capable of containing about 100 pounds of the evaporated sirup. The different sizes are distinguished in the manufactories as *grandes* et *petites bâtardes*, according to their different capacities; they are numbered 1, 2, 3, 4, &c. Moulds made of resinous wood have supplied the place of these in some manufactories; this change was proposed by M. Mathieu de Dombasle, and in those countries where wood is abundant, it is a good one in point of economy.

The moulds must be soaked in water, and then drained, before the sirup is put into them; the opening at the point is stopped with old linen, and the vessels themselves supported against the walls to receive the liquor.

† The sirup arising from the employment of 10,000 pounds of beet roots, if the operations are well conducted, will fill nine *grandes bâtardes*, each *bâtarde* containing from 85 to 90 pounds of evaporated sirup.

When the different boilings are made slowly, or experience any interruption, the moulds are partially filled from the cooler, without

Cooling causes the formation of crystals upon the sides of the moulds and the surface of the liquor. As soon as this crust of crystals has acquired some degree of consistency, it must be broken with a wooden spatula, and the whole contents of the mould carefully stirred, so as to collect in the centre the crystals that have formed upon the sides. When this has been done, the crystallization is allowed to go on undisturbed.

Three days are more than enough for the formation of all the crystals;* the plugs that close the points of the moulds are then taken out, and the moulds are placed in earthen pots, that the molasses may flow from them. †

The crystals will be deprived of the molasses which unites them in about eight days; the moulds are then carried into an apartment which, by means of a stove, is kept constantly heated to 18° or 20° of Réaumur, (= 72.5° and 77° Fahr.) and there placed in fresh pots.

The next operation is that of leaching the contents of the moulds, in order to obtain from them that portion of molasses which refused to flow out. For this purpose the surface of the loaves is carefully broken and scraped with the blade of a knife, so as to smooth it, and then there is thrown upon each one about half a pound of a white sirup, marking from 27° to 30°, (= specific gravity of 1.231 to 1.261.‡) This sirup penetrates into the loaves, diluting and carrying off the molasses, which is three or four degrees more concentrated than itself. If the concentration of the sirup were less, it would dissolve the sugar; if it were more, it would render the sugar adhesive. This op-

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waiting for the last product; otherwise crystallization would be completed in the cooler, and all the contents of it would form a mass which could not be poured into the moulds to extract from it the molasses.

* The operation may be known to be good,—

1. When the surface of the crystallized mass is dry, so that, in passing the hand over it, neither moisture nor adhesiveness is perceived.

2. When the crust settles and breaks in the centre: in this case the refiners say the sugar *makes a fountain.*

3. The yellow color of the crystals is generally a good indication, but in the case of beet sugar it is unimportant, because the color may have been blackened by the animal charcoal employed when the filtration of the clarified liquor has not been carefully executed; and this color is easily made to disappear by clarification and refinement.

† These pots should be large enough to contain five or six gallons of liquor.

‡ This sirup is only a portion of that which is prepared for boiling.

eration is renewed two or three times at intervals of two days.

When the loaves have remained a month in the store-room, they can be taken out of the moulds; they are then found to be dry and entirely deprived of molasses, and are piled up in the store-house, where they are kept to be refined.

ARTICLE VII.

On Boiling the Molasses and Leaching Sirups.

I MIX the molasses obtained from the brown sugar with the sirups which have been filtrated through the loaves, and proceed to boil the mixture. The molasses marks 23° or 24°, (= specific gravity of 1.190 to 1.199,) the sirup 21° or 22°, (= 1.171 to 1.180,) and the mixture 22° or 23°, (= 1.180 to 1.190.) I throw from 32 to 35 gallons of this mixture into the boiler, and when the heat approaches to ebullition, I add about one pound of animal charcoal, which I mix carefully with the liquor.

The boiling of this liquor is more difficult than that of the sirup which produces the brown sugar, but with care and patience it may be done to very good advantage. This liquor yields at least one sixth of the quantity of sugar that has been procured by the first operation: this product is sufficiently important to render it advisable to boil down the molasses, instead of disposing of it, as is almost everywhere done, for distillation.

If the molasses procured from beets was of the same quality as that obtained from the sugar cane, it could be sold with advantage, but it has a bitter taste which renders it unsalable: it is best then to exhaust it of crystallizable matter, and to subject the remainder to distillation. The difference in the quantity of alcohol obtained from the two kinds of molasses is almost nothing.

Instead of depositing the product of this last boiling in moulds, I throw it, from day to day, into a hogshead open at one end, and thus gradually fill the cask; the sugar crystallizes wonderfully in these vessels, so that they become half full of it.

When this sugar, which I call *molasses sugar*, to distinguish it from the *brown* sugar of the first boiling, is to be refined, the molasses which lies upon the top is dipped out, and the rest is made to flow out through small gimlet holes bored in the bottom and around the circumference of the cask.

The sugar, when deprived of all the molasses which can be made to flow from it, still forms only an adhesive paste, which can scarcely be refined; I therefore put this paste into bags of coarse, strong cloth, and subject it to a strong compression. The sugar thus freed from molasses is very dark colored, but the quality of it is excellent, and it is as easily refined as the best brown sugar.

When the brown sugar boilings *turn badly*, and crystallization in the moulds is imperfect, and, in a word, at all times when sugar is ropy, and parts but imperfectly with its molasses, it is necessary to subject it to the action of the press before attempting to refine it; as soon as it has in this way been freed from all its molasses, it may be refined without any difficulty.*

SECTION III.

On the Refining of Sugar obtained from Beet Roots.

When the sugar is dry, the refining of it is easily performed; all possible pains then should be taken in the preceding operations to free it from all its molasses.

All the operations of refining may be brought under two heads, clarification in the boiler, and whitening in the moulds.

To refine sugar well, it is better not to operate upon too

* In most of the beet sugar manufactories they have adopted the swinging boilers for preparing their sirups; concentration is performed speedily in these, and they have the advantage of being emptied in a moment; but they are useful only when the operation is performed upon dry sugars, like the American, which contain but little molasses. Our beet sugar is never so well drained as the imported sugars are, and requires much more care in the boiling. These boilers appear to me more apt to cause the burning of the sugar than the old kind, and I therefore give the preference to the latter.

large quantities. I have always observed that when I subjected to the same refining process 2000 or 3000 lbs. of sugar, the last boilings were ropy, and each operation less perfect than when performed upon 400 kilogrammes (about 890 lbs.) at one time: it is upon this last quantity that I shall found my calculations.*

ARTICLE I.

On Clarification.

A BOILER four or five feet in diameter and twenty-eight inches in depth is two thirds filled with water, to which lime-water enough to fill the boiler is added; in this mixture is dissolved at a low heat 400 kilogrammes of brown sugar.

The solution must not mark more than 32° (= 1.286) of concentration; if it stands higher, it must be weakened, if lower, more sugar must be added. This state of concentration belongs only to solutions of dry sugar; those of damp sugar must be reduced to 30° or 25°, (= 1.261 to 1.210,) otherwise it will be almost impossible to filtrate them.

The solution is then heated to ebullition. When the temperature reaches 65° (= 178¼° Fahr.) fifteen kilogrammes (32¾ lbs.) of animal charcoal are added to it; the mixture is then carefully stirred and mixed with a wooden spatula; after allowing it to boil an hour, the fire is extinguished.† The boiling liquor is freed from the charcoal by filtration through a coarse cloth, and when the heat has fallen to 40°, (122° Fahr.,) the whites of forty eggs beaten and diluted with several quarts of water are thrown into the

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* I have never been able to assign a reason for this difference, but it actually exists; perhaps it arises from my not being able to complete my boilings in one day, and the clarified sirups having become changed in the boiler; or perhaps a large quantity of sirup may be more difficult to manage than a small one, though the ingredients be combined in the same proportions.

† The quantity of animal charcoal added ought to vary according to the quality of the sugar; that which is dry requiring a less portion than that which is wet.

boiler.* The liquor is then carefully stirred, and is kept constantly in motion till the temperature rises to 70°, (= 180° Fahr.,) when stirring is omitted, and the heat raised to the boiling point.

As soon as the first bubble appears upon the surface, the fire is extinguished; a thick coat of scum forms upon the surface of the liquor, and is removed at the end of three quarters of an hour.

The liquor is filtered through a coarse, thick, rough cloth; if the first portion that passes through be not perfectly clear, it is to be thrown again upon the filter, and this operation is repeated till the liquor appears completely limpid and free from any floating particles. As soon as the liquor is perfectly clear, it is boiled; five or six boilings being formed with the product of the clarification.

The several boilings are thrown into the cooler as fast as they are completed, and from thence into the moulds *four*, which can contain $5\frac{1}{4}$ gallons each. These operations are conducted in the same manner as those which I have described in speaking of brown sugar, but with this difference, that the sugar contained in the moulds is stirred and moved at two different times before it is taken in the mass.

After three days the moulds are placed upon the pots into which the molasses drains, and at the end of eight more, they are removed to the second pots, where the whitening is to be performed.

ARTICLE II.

On Whitening Sugar.

The clarified sugar is dry, of a yellow color, varying considerably in the depth of its hue; the taste is mild and sweet. The process of bleaching removes from it the

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* I have noticed that the whites of eggs coagulate at a degree of heat between 30° and 35° of Réaumur, (=122° and $133\frac{1}{4}$° Fahr.) At that degree, I have proceeded to clarification. In some manufactories I have observed that the whites of eggs were added at the moment of ebullition; but in this case they are immediately coagulated, and the clarification being only partial, the sugar comes

small quantity of sirup with which it is impregnated; it can be effected in three ways, namely, by the use of clay, of alcohol, and of the sirups; the first of these is the one generally employed in the refineries.

When sugar is to be clayed, a hogshead unheaded at one end and furnished with a row of stop-cocks placed one above the other from top to bottom, is partly filled with white clay, upon which water is poured till the cask is full; the clay is then carefully stirred, so that every portion of it may be well washed. This operation is repeated several times, the water of the washings being drawn off as soon as the clay settles, and a fresh quantity turned in, which is stirred in the same manner. The washing is continued till the water no longer appears charged with any foreign substances, when the water is allowed to remain undisturbed upon the clay till this becomes thoroughly divided, so that upon handling it no lumps can be found. When the clay is found to be in this state, all the water is drawn off, and the clay suffered to dry gradually, till it acquires such a degree of consistency as not to flow when placed upon a smooth and slightly inclined board: it is now considered ready for use.

Before placing the prepared clay upon the sugar contained in the moulds, the surface of the loaves is carefully scraped, so as to remove one layer of the sugar, which is replaced by a portion of very white powdered sugar; this is piled up and smoothed very nicely, and then covered over with a layer of clay thrown on with a spoon. The water contained in the clay passes gradually into the layer of white sugar, which it dissolves, forming a sirup which penetrates into the loaves, deprives the sugar of its color, and passes out at the point of the mould.

The clay, being thus gradually deprived of water, shrinks and dries, and is then removed and thrown into the cask to be made use of in new operations.

The upper part of the loaves is rendered white by this first operation; but when the liquid which flows from the opening in the point of the mould is colored, a second claying is performed; in this, however, the clay alone is used, the intermediate layer of sugar being dispensed with.

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out brownish, and they are then to be redissolved three or four times before they attain the desired degree of whiteness; this occasions much labor and expense, together with a great loss of sugar.

The number of clayings to be employed, depends upon the quantity of coloring matter contained in the sugar; two are usually enough to render sugar merchantable; but in order that the sirup may flow off free from any tinge of yellow, three must be employed.

When the operation of claying is completed, the loaves are placed upon their bases, that the white sirup by which the points are softened may diffuse itself through the mass.

At the end of eight or ten days the loaves are taken out of the moulds and placed in a stove-room, in which they are dried.

The method of whitening by clay is certain, but it possesses the great fault of converting into sirup nearly $\frac{1}{5}$ of the sugar operated upon; and if the sugar is adhesive, or the grains of it very fine, the quantity of sirup formed is still more considerable. Whenever I have worked upon sugars of this description, I have melted them over, and freed them from their adhesiveness, by boiling them down with a quantity of animal charcoal.

Brown sugar made from beets, when refined, generally yields in molasses or *nonconverted sirup*,* between $\frac{1}{5}$ and $\frac{1}{6}$ of its own weight, and it loses by claying at least $\frac{1}{4}$.

The sirups which are produced during these various operations, are usually boiled without the addition of any foreign substance, and the product of these boilings is thrown from the cooler into the *demi-bâtardes,* where they become crystallized; these form the large loaves of sugar, weighing between 22 and 27 lbs. known in commerce under the name of *lombs.*

It has been attempted to substitute the method of whitening by alcohol for that by claying; this process is founded upon the power which alcohol possesses, of dissolving the coloring principle without acting upon the sugar. I followed this mode two months, making use of no other alcohol than what I procured from the distillation of my molasses. I confined myself in this process to leaching the loaves of sugar contained in my moulds with alcohol of 35° (= sp. gr. 0.852) of concentration; covering the moulds over so as to prevent loss by evapora-

* The molasses or sirup which flows from the mould when it is put upon the earthen jar after crystallization is called *nonconverted sirup;* that which is procured by claying, *converted sirup;* the last is purer, lighter colored, and better tasted than the first.

tion, and renewing the alcohol till the liquor passed off perfectly clear from the point of the mould; this alcohol I redistilled, to employ in new operations.

I abandoned this method of bleaching sugar for the following reasons.

1. Notwithstanding all the precautions I took, I lost half a kilogramme (a little more than a pound) of alcohol for each loaf of ten pounds' weight.

2. The loaves of sugar, though well dried in the stove, always preserved a slight odor, which became more sensible after their having been confined in the papers and transported.

3. The price of alcohol of this degree of concentration, rendered the refining by alcohol as expensive as that of clay.

Some very skilful chymists propose to supply the use of clay by that of sirup; theory is in favor of this method, but experiment contradicts it.

In the first place, in order that the sirup may be employed with success, it is necessary that it should be white, and of course that it should be made by saturating water with very white sugar. The water which is disengaged from the clay produces a sirup in passing through the layer of sugar with which the loaves are covered; there is, therefore, no advantage to be derived from the use of sirup on account of its containing sugar, and the process is less economical than claying, inasmuch as both time and fuel * are required for making the sirup, whilst in claying it is produced by the process itself.

However, as the theory is seducing, I tried this method, and the following statement exhibits the results.

I prepared a quantity of sirup at 30° † (= 1.261) of concentration, which I poured upon the smoothed surface of the loaves till they were covered with it; the following day the sirup had penetrated into the mass, which was sensibly whitened by it. I repeated the operation at intervals of four hours, till the sirup passed off through the point of the mould clear; this did not take place till the

* I say fuel, because water will not dissolve so much sugar by remaining upon it at the temperature of the atmosphere, but that it will take up still more in filtrating through it; so as to increase in concentration 3° or 4°.

† This is the point to which it is necessary to carry it, that it may not dissolve the sugar when cold.

end of twenty days, at which time the bleaching of the greater part of the loaves was completed. I continued the operation upon the others from twelve to twenty days, removing successively those that were finished.

When I came to take these loaves from the moulds, they came out in fragments; the sugar was moist and without consistency; it was impossible to dry it, and I was obliged to melt it over and make double-refined sugar of it. I repeated the operation of bleaching with sirup several times, and always obtained the same results.

It is evident that the sirup applied in this manner interposes itself between the molecules of the sugar, and there remains; whilst in the process of claying, the sirup, being formed gradually, passes through it by insensible filtration, imbibing the coloring matter, which it at length carries off. I moreover found that it required twice as much sugar to form the sirup as was needed in the usual method of claying.

The numerous experiments which I have been in the way of making during a dozen years, have induced me to adopt a process which appears to me to be more advantageous than either of those of which I have just spoken. I cut out of the coarse cloth called *calmuck*, round pieces of the same size as the bases of the loaves; these I soak in water and afterwards wring; I then apply them carefully to the bases of the loaves, which have been previously scraped and smoothed with the blade of a knife, or a small trowel. In twenty-four hours' time the surfaces of the loaves are bleached. I then pour upon the cloth about half a pound of the *converted sirup* of the last claying; the sirup gradually penetrates the cloth, and filtrates through the loaves, from which it removes all the coloring matter.

As soon as the sirup has passed through the cloth into the sugar, I moisten the cloth by sprinkling it with drops of water, and the next day I throw upon it the same quantity of *converted sirup*.*

This first operation is completed in five or six days, after which the sirup is left to flow during four or five days. By these leachings the loaves are perfectly bleached to the depth of four or five inches, but they are still a little

* I here suppose that I operate upon moulds of *four*, the loaves from which weigh from 11 to 14 lbs.

colored below; I complete the bleaching by a slight claying, applying the earth immediately to the surface of the loaves without any intermediate layer of sugar.

I find that bleaching is performed more speedily and with less labor in this way; the evils arising from the use of sirup alone are obviated, and but a small portion of sugar already bleached is dissolved.

In order to appreciate all the advantages arising from well-conducted operations, it is necessary that one should know the change produced in sugar by repeated meltings; it is brought first to a point when it will no longer crystallize, and afterwards to the state of molasses. Sugar which has been three or four times boiled over, will still crystallize upon the sides of the moulds, but the middle of the loaf will be only a uniform, thick, white mass, destitute of the agreeable taste of sugar; this substance, if melted, does not again become solid, but remains in the state of molasses.

I ought to mention, that in the various operations that are performed upon sugar, the nature of the substance is often made to undergo a series of changes or a succession of degenerations equally constant and regular.

I have just mentioned that when sugar is made to repass two or three times through the boiler, it is rendered uncrystallizable, and the middle of the loaf is found to consist of a uniform mass of the consistency of butter, not possessing the agreeable flavor of crystallized sugar. This mass, dissolved in water and concentrated by heat, is reduced to molasses; and when the evaporation and clarification of the juice of beets is prolonged beyond a certain time, nearly all the sugar is reduced to molasses, and the boiling is rendered long and difficult; when this is the case, the sirup throws up an abundance of adhesive white foam, which, when removed with a skimmer, thickens and presents all the characteristics of vegetable wax. The experience of twelve years has uniformly furnished me with these results.

I am thoroughly convinced that these alterations would be avoided by evaporating the sirup in a vacuum; it has even occurred to me that the animal charcoal produced good effects only by its opposing the action of the oxygen of the atmosphere upon the sugar, since nearly the same results are obtained by the use of butter and other oily substances susceptible of extreme division. The secret of causing this decomposition to retrace its steps, still remains to be discovered; I have essayed it without success.

SECTION IV.

On the Distillation of Beet Molasses.

The molasses from beets, when exhausted of its sugar, has not the pleasant taste of that furnished by the sugar-cane, but retains a bitter taste which renders it fit only for distillation.

The product in molasses is as great as that in sugar: each of the *grandes-bâtardes* in which the product of the first boiling is crystallized, yields 40 lbs. of molasses, and 45 lbs. of brown or unrefined sugar: these 40 lbs. of molasses, boiled over, produce 6 lbs. of sugar and 34 lbs. of molasses; thus from two boilings are obtained 34 lbs of molasses, and 51 lbs. of brown sugar.

As this sugar is not pure, it is necessary, in order to refine it, that it should be melted down, crystallized, and whitened. By these operations some molasses and some sirup is extracted from it. The molasses flows from the moulds when they are placed upon the jars, after the brown sugar has crystallized; the sirup is formed during the process of claying; this is boiled over to obtain the sugar dissolved in it, and the molasses remaining is mixed with that in the jars to be distilled.

The weight of molasses obtained by these various operations is nearly equal to that of the brown sugar.

Supposing that I wish to produce the fermentation of 445 lbs.* of molasses, to prepare it for distillation; I proceed in the following manner. I throw the whole quantity of molasses into a vat, and there add to it such a quantity of water as shall cause the liquor to mark 7° or 8° (= 1.052 to 1.060) of concentration. I stir the mixture with the greatest care, so as to unite the two fluids thoroughly. The vat is situated in an apartment of the manufactory, where the temperature is, by means of a stove, kept constantly

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* I usually operate upon 890 lbs. The vats in which fermentation is carried on contain 581 gallons.

at 20° or 22°, (probably of Réaumur,) (= 77° and 88½° Fahr.) and I take care that the liquor be raised to 15° or 16°, (= specific gravity of 1.116 to 1.125,) before the yeast is added to it.

To make the leaven, which must be prepared on the morning of the day in which it is to be used, I form 25 lbs. of rye meal into a paste with molasses, and then dilute the paste with boiling water, to which I gradually add one quart of pure molasses, kneading the mass thoroughly till it is of the consistency of porridge: the heat of it in this state should be 20° or 25°, (=77° to 88° Fahr.) When this leaven is formed for a first operation, a little beer yeast or leaven of wheat flour should be added to it. The bucket is covered over, and set into a place sufficiently warm to produce fermentation: the yeast soon begins to swell, and rises seven or eight inches in the bucket; at the end of twelve or fourteen hours it is ready for use.* The yeast is thrown by small portions at a time into the vat, the liquor in which is stirred during the whole time.

Fermentation commences in the course of two or three hours, and continues two or three days.

The concentration of the liquid is gradually diminished, and at the end of the operation falls to 2°†, (= specific gravity of 1.014.)

The next process is that of distillation: the liquor is poured into the boiler of the alembic through a cloth strainer, by which all the meal and bran contained in it are separated; without this precaution, the liquor would often ascend during distillation into the worm.

When distillation is carried on in the improved alembics, the first alcohol which passes marks 36° (= 0.847) of the hydrometer; it becomes gradually weaker till it stands at only 10° or 12°, (= specific gravity of 1.000 to 0.987;) the operation is then arrested. The mixture of the products forms spirit marking from 22° to 25° (= specific gravity of 0.932 to 0.906.)

The after-taste of this spirit is so bitter as to diminish its value in commerce: I have been able to correct this

* Before making use of this yeast, about one sixth part of it is poured into a separate vessel, to be used in the next preparation of yeast that may be needed; so that in the subsequent operations only 20 lbs. of meal are required instead of 25 lbs.

† Those substances foreign to the saccharine principle contained in beets do not ferment; they therefore prevent the degree of concentration from being less than 2°.

fault by mixing about $2\frac{1}{4}$ lbs. of animal charcoal with the liquor of each boiling; this is 90 gallons: the spirit obtained by this process differs but little from wine-brandy.

I redistil nearly all the spirit over a naked fire, employing for it the same proportion of animal charcoal, and convert it into alcohol of 34°, (= 0.858.)

The sale of the alcohol is more easy and profitable than that of the spirit, as this quality of alcohol is in much request amongst the manufacturers of colors for dissolving their resins.

I once thought, that it would be more advantageous to leach the mash of the beets in order to mix the juice thus obtained with the molasses, and to ferment them together, but experience has undeceived me; the juice ferments, and the molasses does not then undergo decomposition; it is found in the boiler unchanged. I have found the same results to be produced, when I have mixed the must of grapes with molasses.

200 kilogrammes ($445\frac{1}{2}$ lbs.) yield upon distillation about 13 gallons of spirit of 22°, (= 0.932;) these 13 gallons produce $6\frac{1}{2}$ gallons of alcohol at 34°. The expenses of the operation may be calculated thus:

One man, who conducts all the operations, and completes the distillation of it in one day, .	1 franc	50 centimes.
Ten kilogrammes of rye, ...	1	
Pit coal, ...	3	
Animal charcoal, ...	0	50
Total,	6 francs 0 (= $1.14.)	

The conversion of this spirit into alcohol of 34° costs as follows:

Day's wages, ...	1 franc .	50 centimes.
Pit coal, ...	3	
Animal charcoal, . .	0	50
Total,	5 francs	0

From this it appears that the profits are not great, but distillation gives an actual value to molasses which is worth nothing.

SECTION V.

On the Products of a Beet Sugar Manufactory.*

In estimating the value of the products of a sugar manufactory, I will suppose that 10,000 lbs. of beet roots are operated upon each day; however, as beets cannot be employed till after they have been carefully trimmed, there is perhaps a loss of $\frac{1}{6}$ part of that weight; thus, in order actually to work upon 10,000 lbs. of beets, it is necessary to employ 12,000 lbs. so as to allow for this loss.

The products of a sugar manufactory are of two kinds; the first consists of the sugar, the second is furnished by the molasses, the mash, and the trimmings of the beet roots.

ARTICLE I.

Of the Product in Sugar.

The product of the concentrated sirup obtained from 10,000 lbs. of trimmed beets will fill eight moulds, each of which will contain 47 lbs. of good brown sugar; this makes . . . . 376 lbs.

The molasses obtained from the moulds furnishes $\frac{1}{6}$ as much sugar as is obtained by the first operation, equal to $62\frac{2}{3}$

Total, $438\frac{2}{3}$ lbs.

This quantity of brown sugar will, when refined, produce at least $\frac{40}{100}$ of very good double refined sugar; and $\frac{15}{100}$ of sugar of an inferior quality obtained from the molasses and sirups; the whole quantity of sugar being $\frac{55}{100}$.

According to this, the average quantity obtained by an operation skilfully conducted is,

In sugar of the first quality, ... 187 lbs.

In sugar of the second quality, . . . 60

Total, 244 lbs.

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* In the estimate which follows, I have always valued the products at the lowest rate, and the expenses at the highest.

ARTICLE II.

On the Secondary Products.

The operations upon 10,000 lbs. of beets per day produce,

In mash, ...	2,511½ lbs.
In molasses, about	280
The trimmings of 10,000 lbs. .	2,226

ARTICLE III.

On the Value of the Products.

84 kilogrammes (187 lbs.) of good refined sugar, at 2 francs 5 centimes per kilogramme, ...	210 francs	0
30 kilogrammes (60 lbs.) of middling sugar, at 2 francs 25 centimes per kilogramme, ...	67	50
	Total, 277 francs	50

To give a value to the secondary products of the operation upon 10,000 lbs. of beet roots, it is necessary to deduce it from the price which they bear in commerce, or from that of the articles, the places of which they supply.

1. I have estimated the weight of the trimmings of 10,000 lbs. of beet roots to be 2,000 lbs.; but these trimmings contain nearly ½ their weight in earth, and are fit only for feeding swine; they will supply the nourishment for twenty-five or thirty of these animals during the time that the operations upon the beets are continued. The value of the trimmings may be fixed at two francs and fifty centimes.

2. The product in mash is far more valuable; this substance forms excellent food for animals, especially horned cattle: cows and sheep that are fed upon it give large quantities of milk.

The mash contains about $\frac{65}{100}$ of the nutritive principle of the beets, since only water and about $\frac{9}{100}$ of sugar or molasses can be extracted from them.

This article of food does not produce the same evil as dry fodder, which lessens the quantity of milk, and obstructs the intestines of neat cattle, neither does it produce the purging and leanness, which are often occasioned by the use of green and watery herbage.

The mash is prepared in winter, and it is at that season that animals experience the greatest need of this kind of food.

One kilogramme of this mash and one quarter of a kilogramme of dry fodder, is more than enough to feed a merino sheep that gives suck.

If the price of the mash is estimated at only twelve francs per 1000 lbs., the value of the mash each day will be thirty francs.

3. As the molasses has no other value than that which it receives from distillation, it can be estimated only by the products of this operation; and as the price of spirit varies greatly, it is impossible to settle it.*

I do not think that the value of the molasses should be estimated higher than nine francs for 50 kilogrammes; 10,000 lbs. of beet roots produce 130 kilogrammes; this is then an amount of twelve francs per day.

Table of the Products of the operations upon 10,000 *lbs of Beet Roots per day.*

Nature of the Products.	Weight.	Value.
1. Refin'd sugar, 1st qual.	84 kilogrammes	210 frs. 0 c.
1. Refin'd sugar, 2d qual.	30	67 " 50
2. Trimmings	1,000	2 " 50
3. Mash	1,250	30 "
4. Molasses	130	12 "
Total	2,494 kilogrammes	322 frs.

Whilst enumerating the products of beets, I have neglected one, which is however of some importance; it is the leaves. As soon as the middle of August, the leaves may be trimmed off to feed animals; at the season of digging,

* Since my establishment was formed, I have sold alcohol of 35° (= specific gravity of 0.852) at various prices between 160 francs and 500 francs per cask.

an immense number of cows and sheep may be fed for eight or ten days upon the leaves and necks that are cut off and thrown upon the ground.

SECTION VI.

On the Expense of a Beet Sugar Manufactory.

It is not enough to estimate the products of a sugar manufactory, in order to know whether the business can be carried on to advantage; a valuation of the expenses must likewise be made: in this, as in the foregoing part of my statement, I shall give only the results of my own experience.

The expense of the necessary accommodations and utensils required for operating daily upon 10,000 lbs. of beet roots cannot be defrayed with less than 20,000 francs.

If a permanent stream of water and a wine-press can be made use of, the expense may be reduced to 16,000 francs.*

1. The principal article in the expenses of a manufactory of this kind is the cultivation of the beets. Estimating the price of 1,000 lbs. at ten francs, is placing it at a rate by which the manufacturer will escape injury.†

* I do not include buildings, since such as are necessary for this manufacture are to be found almost every where.

† If the proprietor of a manufactory should cultivate the beets himself, sowing his fields with corn immediately after digging the roots, the expense of the preparatory ploughings performed in the winter and spring, and that of the manure and transportation, would be borne entirely by the crops of corn, and there would remain to the charge of the beets, which form an intermediate harvest, only the cost of sowing, weeding, digging, and transportation; thus the price of these will be greatly diminished.

It is easy to estimate upon this ground the cost of the beets to a manufacturer who cultivates them himself: I will here give the estimate of costs for a single acre.

Purchase of six pounds of seed	6 francs.
Sowing the same	12
Two weedings	22
Digging	20
Transportation	20
Storing	3
Rent of the land	40
Taxes	10
	Total, 133 francs.

Estimating the mean product at 20,000 lbs., the cost to the farmer

Thus, 12,000 lbs. of roots being made use of each day, in order that 10,000 lbs. may be prepared for the rasp, the cost will be . . . . 120 francs.

2. The trimming of 12,000 lbs. at the rate of 60 centimes per 1,000 lbs. of trimmings, ...	7	20 c.
3. Wages of eight women employed to tend the rasps, carry the beets, &c. reckoned at 60 centimes per day,	4	80
4. Hire of man and two horses for the establishment, ...	7	25
5. Two men for the presses, . . .	2	50
6. Inspector of the rasps and presses,	1	50
7. Two men to the boilers, . . .	2	50
8. 50 kilogrammes per day of animal charcoal, ...	13	
9. Value of coal consumed,* . . .	25	
10. Salary of the head refiner, . . .	5	
11. Salary of a second refiner, . . .	2	25
12. Lighting of the building, . . .	1	50
	Total, 192 frs.	50 c.

This list comprises only the expenses of a day's labor; if the operations should be continued one hundred days, the expenses would amount to 19,250 francs.

When the preparation of the juice and the manufacturing of the brown sugar are completed, all the work people, excepting the two refiners, are dismissed; these are enough for carrying on the operation of refining. The expenses attendant upon this last operation, which continues till autumn, are as follows:

1. Wages of the head refiner, . .	1,000 francs.
2. Wages of the second refiner, .	500
3. Wages of a laborer, ...	250
4. For animal charcoal, ...	300

of 1000 lbs. is 6 francs, 65 centimes. The expense of labor and manure are borne by the corn which is sown immediately after the digging of the beets; the crops of corn are improved by interposing the crop of beets between them, as the earth is rendered light, and the frequent weedings free the ground from all injurious plants.

* This price is based upon the situation of my own works in Touraine, two leagues distant from the mines: it must vary with the distance and the difficulty of transportation.

5. For pit coal, ...	700
6. For whites of eggs, ...	100
7. For pipe clay, ...	50
Total,	2,900 francs.

To these expenses must be added the following:

1. Interest of the funds employed in furnishing the manufactory, ...	1,200 francs.
2. For repairing and replacing utensils of all sorts, ...	1,500
3. For purchasing bags, strainers, and other small matters, ...	700
	3,400 francs.

Thus the actual amount of expenses of all kinds attendant upon working 1,200,000 lbs. of beets, amounts to	25,550 francs.
I have already proved the product per day to be 322 francs; this would give, for one hundred days of effective labor, . . .	32,200
This allows to the manufactory a profit of	6,650 frs.

The calculations are exact, and deduced from the results of a well-conducted process. A variation from them can only be produced by local situations. But experienced agriculturists will perceive, that I have placed certain expenses at the highest rate, whilst some of the receipts are estimated at the lowest. There are but few sections of France, where pit coal is as dear as it is in Touraine, where my establishment is situated. There would be, almost everywhere else, a considerable saving in this article. I have rated the value of the mash only at 12 francs per 1,000 pounds, although it is very nearly as valuable for feeding animals as an equal weight of dry fodder. I have estimated the price of the roots at 10 francs per 1000; but this is more than they would cost a landholder, especially if he should sow corn immediately after the beets are dug. I have set no price on the leaves of the beets, and yet these will furnish food for the animals of the farm from the middle of August till the end of October.

But, whatever profits this manufacture is capable of affording, it must always be remembered that a want of skill in the operations, or negligence in the preservation of the roots, must occasion some losses in an undertaking, which, even at the low price at which I have estimated sugar, promises sufficient remuneration in the hands of an intelligent man.

SECTION VII.

General Considerations.

From twelve years' experience I have learned, in the first place, that the sugar extracted from beets differs from that of the sugar-cane neither in color, taste, nor crystallization; and, in the second place, that the manufacture of this kind of sugar can compete advantageously with that of the sugar-cane, when the price of this last is in commerce one franc and twenty centimes per demi-kilogramme (= $18\frac{1}{2}$ cents per pound.*)

These facts being established and acknowledged, it may be asked whether the manufacture of beet sugar would be advantageous to agriculture.

The cultivation of beets will not prevent the production of a single kernel of wheat, since this may be made an intermediate crop, and the sowing of it commenced as soon as the beets shall be dug. The crops of corn are better upon these lands than upon others, because the beets have divided and loosened the earth, and the weedings have cleared it of strange plants.

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* It is objected, that beet sugar of bad quality is thrown into the market. I do not contradict the fact; but it only proves that the sugar was badly made. During ten years, the sugar from my manufactory has been sold at the same price as that from the sugar-cane of the same degree of refinement; and not the slightest difference between the two has ever been perceived.

It is said, that the greater part of the establishments of this kind have been given up, after having occasioned loss to the proprietors. This, also, is a fact which I shall not dispute. But I must remark, that this new branch of industry, like all others, requires some knowledge and apprenticeship. It needs to be conducted by men accustomed to similar operations; and it is not at all surprising, that these have not been everywhere found.

It is impossible to mention any kind of manufacture amongst those that have succeeded, where perfection has been attained at once.

The operations upon 10,000 pounds of beets per day, place at the disposal of an agriculturist about 1250 kilogrammes (= 1¼ tons) of mash, which is the best kind of food for horned cattle.

The working of the beets being performed in winter, furnishes employment to the men and cattle of a farm, at a season when they are too often condemned to idleness.

Finally, if the manufacture of sugar from beets should be carried to such an extent as to furnish a supply for all France, agriculture would receive from it the value of more than 80,000,000 francs per annum.

The prosperity of an establishment of this kind, depends upon its being connected with rural labors. This kind of manufactory is out of place in towns, because buying beets is much more expensive than raising them, the mash cannot be rendered productive, labor and fuel are more expensive, and there is not, as upon a farm, a supply of labor both of men and animals.

But can this manufacture be reconciled with the interests of our colonies?

Before the revolution, this would have been a difficult question to answer. Then, our colonies not only supplied our own wants, but furnished an overplus worth about 80,000,000, which we exported to foreign countries, particularly to those of the north of Europe. From these we received in exchange timber, iron, copper, hemp, tallow, tar, &c. The loss of our principal colonies has caused this important trade to pass into other hands, and those colonies that remain to us do not furnish sugar enough for the consumption of our own country.

The government has, at this time, two ends to attain, one of which is, the advancing of the welfare of our colonies, and the other, the encouragement of the manufacture of beet sugar. Both would be accomplished by prohibiting the importation of foreign sugars. When this is done, the sugar of our colonies will find an advantageous market, and the manufactories of beet sugar will increase in number.

Supposing the wants of France should be supplied by the sugar from beets, — could we not then resume our commerce with foreign nations, by means of our colonial sugar? France would, at the same time, be safe from the danger of privation, and from those variations in price which are produced by a maritime war.

It is a fact that if the government do not interest itself seriously in this important subject, neither the colonies nor the manufactories will ever acquire a great degree of prosperity; and one of the finest discoveries of modern times will be lost to France.

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