
CHEMISTRY
GEOLOGY
BOTANY
METEOROLOGY
AGRICULTURE

SCIENTIFIC AGRICULTURE,

OR THE ELEMENTS OF

CHEMISTRY, GEOLOGY,

BOTANY AND METEOROLOGY,

APPLIED TO

PRACTICAL AGRICULTURE.

BY M. M. RODGERS, M. D.,

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ILLUSTRATED BY NUMEROUS ENGRAVINGS, & A COPIOUS GLOSSARY.

Nature maintains uniformity in the operation of all her laws, and produces nothing by chance: whenever, therefore, we observe an apparent exception to this principle, it is due to deficiency of knowledge or error in conclusion. And whoever practically disregards this truth, and rests his hopes upon contingent events, will be compelled to correct his error at his own cost.

ROCHESTER:

PUBLISHED BY ERASTUS DARROW,

CORNER OF MAIN & ST. PAUL STREETS.

1848.

BENTON & FISHER, PRINTERS,
Reynolds' Arcade, Rochester.

TO

HON. ZADOC PRATT,

THIS VOLUME IS RESPECTFULLY DEDICATED BY

THE AUTHOR.

PREFACE.

No apology ought to be required for the appearance of a work like this: the importance of the subjects discussed should secure at least an impartial examination.

But from the humiliating consciousness which the author feels of his own inability to do justice to so difficult a task, he is induced to say something by way of explanation, in order if possible, to put himself upon friendly terms with his readers. The importance of an enterprise, however, furnishes no reason to an incompetent person for attempting its prosecution.

If, after the book has passed the trial of the public prosecutors in behalf of science, the *critics*,—they shall decide against it, the author has no alternative, but must plead guilty: neither will he claim indulgence on the ground of its being the first offence, or plead, in extenuation of his fault, his ignorance of the law in relation to the case.

But a sincere desire, (augmented by personal considerations,) to aid in the diffusion and cultivation of science, has induced him to make an effort, which may not be regarded by liberal minds as altogether inexcusable.

The practice of issuing crude and imperfect books, is a fault quite too prevalent at the present day: there are already too many mere alphabets of science, abridgements, and books of learning made easy; their tendency is to make conceited and superficial scholars, without the labor of personal observation and patient study.

But the elements of any science may be so explained and arranged, as to give a synopsis which may be of much service to the student; and when these elements are learned, he has laid the foundation for future advancement by his own observation. Plainness and brevity have been studied, and technical language avoided as much as possible; a glossary has been appended which explains such technical terms as were indispensible. It is needless to say, that a treatise on science cannot be entirely divested of all difficulties, and couched in language which is at once simple and expressive.

It was deemed better to give the rudiments of each science, in a separate systematic treatise, than to intersperse them through the whole book without order or method. A reader will profit more to have the principles given in this way, that he may apply them himself,—than he will to have a perfect system of agriculture made up of them all, without systematic arrangement.

Another advantage of such a book is that the general reader may obtain the first principles of Chemistry, Geology, Botany or Meteorology, without reading a large amount of agricultural science, which, to him, may be of little use.

The author is aware that an amount of matter is embodied in this book sufficient to make, when extended and amplified, several such volumes: but nearly all books contain much by way of explanation and *speculation*, that could well be omitted. Some things may be found in the book which do not appear to have any direct connection with practical agriculture; but a little observation shows that the sciences discussed all have such a connection and relation, that to omit any principle would destroy the harmony of the whole system.

The best authorities have been consulted,—so that whatever may be open to criticism must be judged by their testimony. It is desirable that the agricultural community, for whose more special use the book is designed, may be disposed to favor the enterprise: with all its faults, therefore, it is respectfully committed to them—and the public;—with no claims except to their forbearance, and no means of propitiating their favor, beyond its own merits.

M. M. RODGERS.

Rochester, August, 1848.

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ACKNOWLEDGEMENTS.

THE Author acknowledges with pleasure, the valuable assistance of several scientific and practical gentlemen, to whose names he is permitted to refer—viz:

CHESTER DEWEY, M. D., Professor Chemistry, Geology, &c.
JOHN J. THOMAS, Esq.
L. WITHEREL, A. M.
P. BARRY, Esq.
L. B. LANGWORTHY, Esq.
AARON ERICKSON, Esq.
D. D. T. MOORE, Esq.
N. GOODSELL, Esq.

Several of the above named gentlemen have examined portions of the manuscript of this book, and made such suggestions and corrections as they thought necessary.

They should not, however, be held responsible for any statement which may appear to be erroneous, or for the selection and arrangement of the topics discussed. M. M. R.

INTRODUCTION.

Agriculture is doubtless one of the oldest, most honorable and important pursuits among civilized nations. Without it the food of man must have been limited to the flesh of wild animals and the spontaneous productions of the earth: Commerce could not exist to any extent; the arts and sciences would be almost unknown; and society could not advance in improvement beyond a refined state of barbarism. But the culture of the soil enables men to produce more of the necessary food than they require, so that a part only are required in this pursuit, while the remainder are enabled to turn their talents and ingenuity to some other useful calling, the products or services of which are given to the agriculturist in exchange for food.

This is the origin of the division of labor, which is at the foundation of all political economy and true governmental policy: this division and subdivision of labor is adopted more extensively the more a nation becomes enlightened and prosperous. Without such distribution of pursuits, little wealth could be accumulated by nations or individuals. In order that every man should be independent of the services of all others, he must manufacture and produce every thing with his own hands which in the social and civilized state of society, he receives from them: this would so occupy his time and talents that he could only produce the bare necessities of a primitive life: his food must be obtained by hunting, fishing and digging roots,—his clothing, the skins of animals,—his shelter, a rude hut, and his only beverage water.

From this mode of living, also, the earth must soon contain more inhabitants than could subsist on its spontaneous food, and part must die of starvation.

The art of agriculture has been known and successfully practiced by some of the oriental nations from remote ages.

The Chinese appear to have a good practical knowledge of soils, and have, by industry and skill in agriculture, sustained a population of an almost incredible number: and, although they are supposed to be but little removed from barbarism, they are said to excel all other nations in the amount of food which they produce from a given space of soil.

That the ancient Romans had an amount of practical knowledge equal to most nations of the present day, is evident from the following passages from Virgil's Georgics. Thus in his first Georgic he alludes to the rotation of crops, the art of manuring and burning land.

> "Yet shall thy lands through easier labor rear
> Fresh crops by changeful produce year by year,
> If rich manure new life and nurture yield,
> And ashes renovate the exhausted field.
> Thus interchanging harvests, earth repair;
> Nor lands unplowed, meantime no profit bear.
> Much it avails to burn the sterile lands,
> And stubble, crackling as the flame expands;
> Whether earth gain fresh strength or richer food,
> Or noxious moisture, forced by fire exude;
> Whether it draw through many an opening vein,
> Juice to fresh plants that clothe anew the plain,
> Or brace the pores, that pervious to the day,
> Felt the prone sun's intolerable ray,
> To piercing showers the expanded fissure close,
> And the chill north that blisters as it blows."

Again in the second Georgic we have evidence that they studied the nature of, and adapted various crops to different qualities of soils.

> " Now learn the soils, the nature of each field,
> What fruits their varying strength and virtue yield;
> Know first, the ungenial hill and barren land,
> Where sterile beds of hungry clay expand,
> And thorns and flints deface the rugged earth,
> Demand the long lived plants palladian birth."

In the other three Georgics we learn that the Romans understood horticulture, gardening, the management of domestic animals and bees,—and the extermination of noxious weeds and insects. Limited as were their mechanical means, and their knowledge of chemistry, geology and botany,—still their skill and success would seem to exceed that of agriculturists of the present day; and in fact we may almost believe that the practical knowledge of farming has retrograded since that time. If this is the case, it cannot be because science has been detrimental to modern practice,—but is rather owing to their close observation of nature, and their attentive industry. It is no argument against the art of culture being conducted on scientific principles: the success of practical men is due to the discovery and carrying out of these principles, although they may be ignorant of them, and may not recognize them as such. The idea that the farmer requires nothing but practice and experience to ensure success, is as erroneous as to suppose the school teacher requires no knowledge of arithmetic or grammar. Not a blade of grass can be made to grow without perfect conformity to the laws of nature,—and still the farmer arrogates to himself the credit of success in an operation, the philosophy of which he neither does, nor desires to understand.

The failures of practical men in attempting to apply some new principle, are owing to want of knowledge and skill in combining science with practice,—and not to any discrepancy in facts. It must be admitted that many of the processes of successful farming are not yet explained,—and many things, true in theory, are not, as yet, demonstrated in practice, but this does not justify the conclusion that nature is not entirely consistent with herself. Men have been too much disposed to consider certain phenomena as "mysterious and past finding out," and thus have ended their investigations.

But the time has arrived when the application of science is the only means of any great success in agriculture; and those who reject this light must be content to plod their way through life like one groping in darkness,—be considered as wanting in intelligence and enterprize,—to accomplish but little and barely subsist,—while the scientific farmer reaps abundant harvests. However strong the prejudice may be against what is absurdly called "book farming,"—the old empyrical system cannot, in a country where the population is dense, the soil becoming exhausted, and manures scarce, maintain a successful competition with one which is conducted upon scientific principles.

No art or profession presents more points of contact with the various branches of natural science than that of agriculture; and in no pursuit is education regarded as of less importance. While in all the learned professions and many mechanical arts, education is considered indispensible,—the farmer whose knowledge consists of reading, writing, and a few empyrical dogmas of his ancestors, is supposed to be abundantly qualified for his calling. Trained and educated in all the old and established practices of his fathers, he is sceptical upon all that is written, and slow to adopt any new improvement in practice.

An ancient philosopher being asked what things were most proper for boys to learn, replied,—"Those things which they intend to practice when they become men." Now inasmuch as agriculture involves the same branches of knowledge as most other arts and professions, it follows of necessity that the farmer requires the same education and discipline of mind as those do who practice law, medicine, engineering, and the mechanical arts.

Agriculture should not be looked upon as the end of life,—but only as a means of securing the necessary food for subsistence: this, as well as all other pursuits, should be adopted with the view of enabling men not only to improve and beautify the earth, but to cultivate the moral, intellectual and social powers, and to fulfil according to their capacity, their proper station among their fellow men. It should not tend to make men mere machines, who toil for the sole purpose of gratifying grovelling and depraved appetites; but it should elevate and refine to the highest degree of perfection, all the better faculties of our nature.

A large part of the farming community already recognize the utility of the natural sciences in the cultivation of the soil.

Some elementary books have been written which have been favorably received by the farming public. Among the natural sciences, *Geology* has received more attention than any other among this class of men. The connection of this science with agriculture is so apparent to every one who learns but the rudiments of it, that it needs only to be introduced, (in treatises which are plain and well arranged,) to be studied and applied in practice. It teaches the origin and nature of all the various soils and rocks, and all great physical changes which are taking place from natural causes on the earth, and beneath its surface.

Botany is also of much importance: and indeed the agriculturist and horticulturist are the only persons to whom the study and practical application of its principles are indispensible. It teaches the characters, habits and localities of nearly one hundred thousand different species of plants: it treats also of their physiology, and explains many of the most interesting processes of vegetation.

Chemistry is the key which unlocks the great laboratory of nature, and shows us how she performs her complicated processes, and produces all her wonderful phenomena.

Meteorology investigates all the facts and phenomena pertaining to weather, climate, seasons, temperature, storms, latitude, altitude, winds, &c.

Zoology treats of the habits, localities, depredations and uses of all the objects of the animal kingdom. Comparative anatomy and physiology constitute a branch of zoology which treats of the form, structure, functions, differences and peculiarities of all the organs of animal bodies. It is the basis of all knowledge relative to breeding, rearing, feeding, and curing the diseases of animals.

Natural Philosophy treats of the properties and dynamic forces of light, air, water, and the mechanical powers, and their application to machinery and other practical purposes of life. Besides these, many other branches of knowledge are indispensible to the education of the accomplished agriculturist. The study of astronomy, geography, architecture, political economy, algebra, geometry,—a knowledge of the languages, general literature, and the fine arts to some extent,—and in fact we might say, a complete collegiate course, belongs as much to the farmer as to the professional man.

But the means by which this amount of preparatory education is to be attained by farmers' sons, are not yet provided. Various plans for agricultural schools have been proposed, none of which have been successful in this country. Where such schools have been established and endowed with competent instructors, library and apparatus, the number of pupils have been a mere fraction of the young men who were destined for agricultural pursuits. While a few are ambitious of high attainments, the great mass are indifferent, or prejudiced against what they suppose to be only an innovation. In this way the schools fail for want of patronage, and young are deprived of their education for want of schools.

But if we are not yet prepared to sustain agricultural schools, some other plan may be available. The teachers of common schools may be educated in scientific agriculture, so as to be able to instruct all such pupils as are designed for this pursuit, in at least the elements of the most necessary branches. In this way the germs of science will be planted and a taste excited, which will lead ultimately to a thorough and systematic course of study.

This plan, though limited and imperfect in its operation, has the advantage of giving to boys, early impressions, and a preference for those studies, which, if proper books are accessible, may be pursued in connection with practice in after life. A plan has been proposed for securing the agricultural education of teachers, which is to establish a professorship of agricultural science in the State Normal School. By this means teachers could be educated, who would be competent to teach the science to the extent required in the schools of farming communities.

Every farm should be considered a chemical laboratory, and every farmer a practical chemist and philosopher: farming would then be honorable and lucrative. Education would give to the cultivator of the soil that dignified confidence and polish which he has a right to possess,—and which he now too often ridicules or envies in men in other pursuits. No reason exists why rural pursuits should alienate their votaries from the rest of mankind, and give rise to those jealousies and suspicions with which they look upon men of other occupations, or fill the mind with that dogged arrogance which is always the offspring of ignorance.

The profits of productive farming would, when conducted scientifically, enable the farmer to accumulate wealth, and enjoy all the comforts and luxuries of refined life. Every community could be made up of the best society,—every family could have its fine library and its accomplished sons and daughters: farmers' sons need not leave the favorite pursuit of their fathers, and go into the learned professions, from the erroneous conclusion that they were more honorable or profitable. Farmers' daughters need not despise the delightful and healthful employments of the dairy, the kitchen, or the loom,—and seek elevation in the miserable pursuits and fashions of the city.

Nothing conduces more to the elevation and refinement of the mind than the study of nature; the man who holds frequent communion with nature, and studies and obeys her laws, is always made a better and happier man.

The more we explore the mysteries of nature, the more are we humbled with the reflection, that to our finite view, only a small part of her works are comprehensible. And when, after years of patient toil, we fancy we have learned most of her laws, we still find the great Author has only opened to our view new vistas to more extensive and unexplored fields of knowledge.

"Nature is always perfect and unvarying, but man's knowledge is progressive; consequently in every advance he arrives nearer the truth, yet as far from knowing all nature and her laws as he is from infinity. Exact knowledge consists in those things which can be seen and demonstrated,—while in all knowledge of inference there is progression. Opinions, which are often the result of imperfect knowledge, are liable to change, and the mind is never advanced by adopting the opinions of others; for by that means man is never made a thinking being, but rests upon authority In all sciences, the acquisition of new truths exhibits in a new light, the beautiful and harmonious operation of the laws of nature."

Besides the benefit of mental discipline derived from the study of nature, for which agriculture opens as wide a field as any other pursuit, the charms of rural life are unalloyed by the reflection of ill-gotten gain, and uncontaminated by immoral influences. The farmer has no occasion to review with remorse, a life of injustice to his fellow men, or mourn the loss of fortunes accumulated by an occupation almost necessarily dishonest.—The lawyer looks upon his briefs prepared for unjust causes, the physician upon the emaciated forms of his patients, and the speculator upon the wealth amassed from the ruined fortunes of others, with the humiliating consciousness that they have not, in all cases, returned an equivalent for what they have received. But the cultivator of the soil may pursue his calling with the cheering reflection, that an all bounteous Providence has rewarded his efforts, and through him bestowed means of happiness upon his fellow men.

The reminiscenses of rural life and scenes are always pleasant: who would not wish to return to the bounding and joyous days of youth, which were spent among woodland scenes, green fields, along the river's shore, on the sunny hill's side, or in the silence of the cool ravine, where every object lent enchantment to the scene, afforded pleasure without alloy, and prepared the mind for the admiration of nature and study of her laws in maturer years. What haunts so sacred, what objects so linked to our affections, as those associated with rural life in childhood. Who that appreciates the quietude and smiling plenty, the balmy air and variegated landscape of the country,—would not prefer it to the crowded noisy streets, the pestiferous atmosphere and demoralizing influences of the city. It is in the country alone that man enjoys the beauties of nature, as she spreads them out before him in all their wild luxuriance, or as she patiently smiles beneath the improving hand of cultivation.

Agriculture is an honorable, a delightful and a glorious pursuit: the first man who lived on earth was an agriculturist,—and agriculture must exist till the last man leaves it.

But *all* labor is honorable: the GREAT FIRST CAUSE works,—nature works,—and every man who enjoys her fruits, ought to hold it honorable to work. When shall the glorious time dawn, that intelligence and true philanthropy shall annihilate the selfish distinction which pride has made between labour and idleness? May that auspicious day soon arrive when the worthless distinctions between mental and physical labour shall cease to exist, which separates man from his fellow man,—and all the tenants of earth meet as equal sovereigns of our common inheritance.

NATURAL SCIENCE.

NATURAL SCIENCE embraces all the objects of the material creation, from the minutest insect, plant or particle of dust, to the most vast of the celestial spheres. This great field of knowledge is divided into *Natural Philosophy* and *Natural History*. Natural Philosophy elucidates the laws which govern the phenomena of the material world,—and is divided into *Chemistry* and *Physics*. Chemistry treats of phenomena which depend upon a change in the constitution of bodies: Physics treats of the dynamical properties and phenomena of bodies, which do not depend on a change in constitution or elements.

Natural History treats of the character and properties of individual objects: these are divided into three great natural groups called kingdoms,—viz. the *animal*, the *vegetable* and the *mineral* kingdom. Natural objects are distinguished also into two great classes termed *animate-organic* and *inanimate-inorganic*. All the individuals of each of the primary divisions, are again divided or grouped into Classes, Orders, Genera and Species.

The dividing line between organic life and inanimate matter, is not well defined; between the lowest form of organic life and the most perfect and symmetrical crystal of the mineral kingdom, however, the distance must be almost immeasurably great. Passive motion or change, is the peculiar attribute of inorganic matter: it can neither enjoy life, nor be subject to death: but life and organization are inseparable,—to this combination, birth and death, are the necessary and invariable terms of existence.

PART I.

CHEMISTRY.

CHAPTER I.

The science of Chemistry has for its object the investigation of the properties of all elementary and compound substances, their relations and combinations, the agencies by which their changes are effected, and the laws which govern them. The basis on which this science rests, is facts and experiment; and as it is purely a demonstrative physical science, no hypothetical or speculative views can be *practically* made of any service to its advancement and application.

Every change which takes place in the elementary constitution of matter in the universe, whether effected by natural causes or by the operations of art, involves a fixed chemical law, and is due to chemical action.

Chemistry consists of two distinct branches, viz. *Analysis* and *Synthesis*. *Analysis* consists in decomposing a compound body and separating its elements. *Synthesis* consists in uniting simple bodies so as to form a compound substance. The forces which preside over and cause all chemical changes, are, attraction, light, caloric, electricity and magnetism. The relative importance of these several forces cannot be exactly estimated in the present state of the science: the question as to their individual nature, or identity with electricity, remains unsettled.

The science of chemistry, which has achieved greater triumphs over matter, and conferred more practical knowledge of nature upon civilized man than all other sciences combined,—has gradually grown out of the superstitious art of *Alchemy*.

Modern chemistry, instead of alluring its votaries into a fruitless search after the "philosopher's stone," crowns their investigations with results which tend to the advancement of civilization and the increase of human comforts and happiness. Its objects are not limited to the study of abstract laws alone;—but also to the improvement of the useful arts, the cure of disease, the production and preparation of food, the study of the laws of organic life, and finally to every thing affecting our physical relations to the material universe.

PROPERTIES OF BODIES.

CAPILLARITY.

Capillarity is the force by which small tubes and porous substances absorb and raise fluids above the surface of that in which they are immersed. This force depends upon the cohesion of the molecules, or ultimate atoms of the fluid for each other, and the attraction of the solid body for those of the fluid. If we dip the end of a small tube open at both extremities, into a fluid, it will be observed to rise slowly above the surface of the surrounding mass: if one corner of a sponge be dipped into water and allowed to remain, it will by virtue of its capillarity in a little time be saturated; the water having been raised by this force against the antagonizing force of gravity.

COHESION.

Cohesion is the force by which the particles of a homogeneous body are held together and resist separation. Caloric is the opposing or antagonizing force of cohesion. "The three different forms which matter assumes,—viz. solid, liquid and gaseous,—are determined by the degree of the cohesive force existing among the elementary particles." This force is greatest in solids, less in fluids, and least in gases. In gases this force is negative or absent, the particles having a tendency to repel each other. The globular form of the drops of liquids depends upon this force.

It is easy to conceive that if cohesion were to be suspended, all solids as well as fluids would assume the gaseous form; the repulsive tendency beingt henu ncontrolled. This can be effected to a certain extent by means of heat: heat overcomes the cohesive power of solids and changes them to liquids: but when the heat is removed, they are again changed to solids by cohesion,—as in the case of melted iron: bodies naturally liquid, as water and mercury, are volatilized by heat, and assume the gaseous form. The cohesive force acts at insensible distances.

DIVISIBILITY.

Matter is capable of being divided into inconceivably small particles. We have, however, no means of determining the question of its infinite divisibility. We can easily imagine that the minutest particle which can be produced by mechanical means, must still have extension, form and weight, and would be divisible, (had we instruments sufficiently delicate,) into other particles, and these again into others, and so on until they totally disappeared from the limit of our conceptions. But we cannot by any process whatever annihilate or destroy the least particle of matter.

The particles of hydrogen gas, which is itself fourteen times lighter than common air, would, individually present an idea almost inconceivable. And still this gas is material, and must be made up of an aggregate of particles. A single grain of gold used in gilding silver wire, is made to cover a surface of 1400 square inches, and still the gold upon the millionth of a square inch when examined by the microscope, is distinctly visible. A square inch of gold leaf may be divided into one billion and four hundred millions of particles, and still retain all the characters and color of a large mass.

Chemical action may be supposed to carry the process of division to a much higher attenuation than mechanical means. A single drop of solution of indigo colors 1000 cubic inches of water, and yet this coloring matter is an aggregate of distinct particles. The fineness of particles has an important effect on the chemical action of one body upon another. Perhaps a more definite idea may be given by the following example. The author had the pleasure of examining with Professor Dewey's improved microscope, some *fossil infusoria,* which were so small that they appeared like perfectly impalpable powder, and not the least gritty between the teeth. These minute particles of dust when subject to the greatest magnifying power of the instrument, proved to be the shells of infusoria resembling in shape the *sow-bug* and *trilobite,* and apparently from three to four inches in length and one inch in width. And still, minute as they were, they must have had when living, all the organs and machinery of animals of large size.

GRAVITY.

The term gravity, in natural philosophy, signifies weight: it is that force or attraction in nature which causes all bodies to move towards the earth when not prevented by some other force. The gravitating force of a body is in proportion to the quantity of matter which it contains. The force of gravity increases in falling bodies, in proportion as they approach the earth. Bodies of the same bulk, do not always possess the same gravity or weight, owing to difference in density: thus lead weighs about twelve times as much as cork, bulk for bulk,—that is, it contains twelve times as much matter,—and hence it has twelve times the gravitating force.

What this gravitating force is, has not been determined; all we know in relation to it is, its effects. *Specific gravity*, denotes the weight of any body, compared with some other body of equal bulk, which is taken as a standard and is reckoned at unity. Water is taken as the standard of specific gravity for solids and fluids, while atmospheric air is the standard from which the weight of the gases is estimated.

DENSITY.

By density, is understood, the compactness of bodies, or the number of ultimate particles contained in a given bulk: bodies which contain the most particles are most dense,—that is, their particles are in the closest proximity to each other. *Rarity*, or porosity is opposed to density. Density does not depend upon the peculiar kind of matter of which a body is composed, but only upon the proximity of its particles. This is apparent, from the fact that the lava ejected from volcanoes, if cooled on the surface of the earth, produces a stone sufficiently light and porous to float upon water,—while if cooled under great pressure at a distance below the surface, it forms a dense heavy rock like granite.

ELASTICITY.

Elasticity is the property in bodies, which causes them to resume their original form and bulk, after being bent, compressed or condensed. Most solid and hard bodies possess this quality in some degree: glass, ice, ivory, &c. are elastic solids: india-rubber is an exceedingly elastic body,—while wet clay is entirely destitute of this property. The gases are far the most elastic of all bodies.

TENACITY.

By tenacity, we understand the degree of force or cohesion with which the particles of a body are held together,—in other words tenacity means *toughness*. Some substances, as some of the metals, are extremely tenacious, while others want this quality almost totally. The tenacity of the metals varies greatly,—cast steel being the most tenacious of them all, while lead is the least so. The tenacity of the woods varies as does also that of soils: clay soil is tenacious, while sand soil is destitute of this property.

CHEMICAL ATTRACTION, OR AFFINITY.

This is a peculiar power in bodies, which disposes them to unite with other bodies and form compounds. It is the power by which chemical phenomena are produced: it is different from cohesion and all other forces in nature: it acts with various degrees of energy in different elementary bodies,—showing a preference for some, and refusing to act on others at all. Chemical affinity is influenced by many other agents, as heat, electricity, gravity, cohesion, moisture, elasticity and light. An affinity originally weak, may by some of these agencies be made strong, while an affinity originally strong may be rendered weak or, destroyed altogether.

When common salt is thrown in water, it unites with it, (dissolves,) by means of a weak affinity or chemical attraction, —but if oil be thrown into water, it does not unite with it, because it has no affinity for it. Some substances unite in all proportions, as, for example, vinegar and water; while others unite only in definite and fixed proportions, as sulphuric acid and lime, &c. When two substances of opposite natures are brought together, as, vinegar and pearlash, they readily unite, by means of *simple affinity*, and form a third substance different from either of the other two. If now a third substance be added, which has a stronger affinity for one of these two than they have for each other, the two first separate, or are decomposed, and one of them goes to unite with the new substance, and form a compound, by means of *elective affinity.*

Two bodies which have no affinity for each other, may sometimes be made to unite by means of a third: thus, oil and water will not unite alone,—but by the medium of the alkali potash, which has an affinity for both, they unite and form the well known compound, soap.* Chemical union is usually attended with the evolution of heat. Some substances unite without any apparent action, while others have an affinity so strong that union takes place with an explosion. Chemical affinity manifests itself in a more complex form under the name of *double elective affinity.*

When nitrate of ammonia and carbonate of potash are mixed together in solution, a *double decomposition* and reunion take place: the potash leaves the carbonic acid to go to the nitric acid, and the nitric acid leaves the ammonia to go to the potash,—the carbonic acid and ammonia, finding themselves deserted and alone, unite and form carbonate of ammonia. Thus nitrate of ammonia and carbonate of potash are decomposed, and nitrate of potash and carbonate of ammonia formed. This may be more clearly shown by arranging the four elements thus:

Nitrate of Ammonia.	1. Nitric Acid. 2. Ammonia.	3. Potash. 4. Carbonic Acid.	Carbonate of Potash.

This change of elements took place because a stronger affinity existed between 1 and 3, than between 1 and 2,—and a stronger affinity existed between 2 and 4, than between 3 and 4. These compounds might again be decomposed by others, having affinities sufficiently powerful to overcome that which holds them together. In order that bodies may be

* This example is taken from Comstock's Chemistry on account of its plainness; but is nevertheless not strictly true, as the idea of an intermediate substance is now abandoned by chemists. The truth is, that the alkali and oil unite and form soap, which it itself dissolved in the water.

united by affinity, they must possess different chemical properties: thus acids and alkalies are chemically opposed, and are consequently drawn together, while they rarely, if ever, unite with each other. "We might [says Dr. Fownes] define chemical affinity to be a force by which new substances are generated."

LAWS OF COMBINATION.

The elements of chemical compounds are generally limited to fixed and invariable proportions on both sides. It is this constancy of proportions alone, which gives to chemistry its title to the character of an exact science; for had all bodies the property of combining in every possible proportion under every variety of circumstances, no definite or certain knowledge could be obtained in relation to the constitution, properties or chemical uses of bodies: experiments would give results so different and variable, at different times, and under various circumstances, that the votaries of this sublime and useful science would long since have abandoned it in despair.

The elements of a given chemical compound are always in the same proportions: thus, green oxide of iron is composed of 27 parts, by weight, of iron, and 8 parts of oxygen: common salt is a compound of 23 parts sodium and 35 parts chlorine; and these are the smallest proportions in which those elements can be made to unite. When two elements unite in more than one proportion on either side, the additional proportions are just double, triple, quadruple, &c., or 1 to ½—that is 2 to 3,—3 to 5,—the amount of the first: that is, they increase in exact multiple proportions. To illustrate this principle we may allude to the five compounds of oxygen and nitrogen.

Protoxide of nitrogen consists of—

	Nitrogen,	14.06	Oxygen,	8
Deutoxide	"	14.06	"	16
Hyponitrous acid	"	14.06	"	24
Nitrous acid	"	14.06	"	32
Nitric acid	"	14.06	"	40

It will be seen that while the nitrogen remains the same, the oxygen increases by multiples of 8, which is its equivalent number. The nitrogen, although willing to unite with several whole proportions of oxygen, would reject a quarter or half of an equivalent, and not unite with it: so, in the preparation of any compound, if an excess of either element be used, it is not combined, but left alone in its original state.

The equivalent or combining number of a body is that which represents the smallest in which it is known to combine with other bodies. The representative number of a compound, is the sum of the combining equivalents of its components. Combining proportions are reckoned by weight and by volume; in these two estimations of course different equivalent numbers are used.

CHAPTER II.

LIGHT.

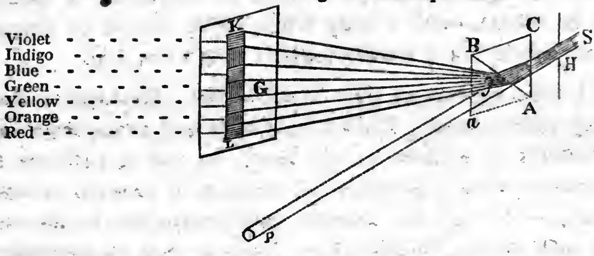
In order to understand the relations of light to vegetation, a short description of its properties is necessary. There are two theories respecting the nature of light: one supposes it to be particles of luminous matter emitted, or thrown off by luminous bodies. The other supposes the existence of a substance called *ether*, which pervades all nature, and is put into a vibrating or wave-like motion by all luminous bodies.

Rays of light proceed in straight lines from luminous bodies, unless interrupted by some intervening medium. Light moves with the astonishing velocity of 200,000 miles in a second of time. When a ray of light falls on a plane surface, it is disposed of in one of three ways: when the plane is black, the ray is all absorbed: when it is polished, the ray is partly absorbed and partly reflected: when the plane is transparent, as glass or water, it may be partly absorbed, partly transmitted and partly reflected. The law of reflection of light is the same as that of sound: when a ray of light falls obliquely on a reflecting surface, it is reflected in the same angle as the one in which it approached the surface; thus the angles of *reflection* and *incidence* are equal.

When a ray of light passes from a rarer to a denser medium, it is *refracted*, or turned out of its course: when it passes from a rare to a denser medium, as from the air into water, it is bent towards the perpendicular: when it passes from a dense to a rarer medium, it is turned from the perpendicular.

Light is a compound of seven colors, viz: violet, indigo, blue, green, yellow, orange and red. The colors can be separated by a triangular piece of glass, called a prism: they possess different degrees of refrangibility, as will be seen by the figure.

Fig. 1. Solar Spectrum.



[This cut shows the solar spectrum in the order of its seven colors: the violet appears most, and the red least refracted.]

There are also *heating rays*, which attend the luminous ones: the calorific, or heating powers of the red rays, are the greatest: these powers diminish in the order of the spectrum, from the red to the violet, which possesses the least of all. Light is a powerful decomposing agent: many chemical compounds, as the salts of silver, are decomposed by the agency of light alone. The influence of light on vegetation is very important, and will be noticed hereafter. The process of taking phtographic and Daguerreotype pictures, depends upon the action of light on a sensitive metallic surface.

There are several *sources* of light: the great source of light which produces the day to our earth, is the sun,—the moon's light is only a reflected light which it receives from the sun. The combustion of bodies is another source of light: another form of light is called phosphoresence, which is emitted by certain bodies, as phosphorus, decayed wood, putrid flesh, certain gases, &c.: this is a feeble light, and is only visible in darkness.

CALORIC.

Caloric is the substance or agent which is thrown off by heated or burning bodies, and which produces the sensation of heat: in common language it is the word used to express both the cause and the effect. This agent possesses no appreciable weight. Although it must be substance, or material in its nature,—still a body when highly heated or charged with caloric, is not sensibly heavier than when cold.

Caloric appears to exist in all bodies. Heat and cold are only relative terms; when a body is so cold as to produce the sensation of coldness to our touch, we call it cold; on the contrary, when it produces the sensation of warmth, we call it warm,—although the absolute temperature may be the same in both cases. Caloric always tends to seek an *equilibrium:* that is, it constantly passes from the hotter to the colder bodies: if a piece of ice at 32° be carried into an atmosphere where the temperature is 60° below 32°, it will, in changing its temperature to that of the surrounding air, give off 60° of heat: this illustration is sufficient to prove that the ice really contains heat.

The *expansive* power of heat is another property which involves many important facts: when caloric enters a body, it is supposed that a mutual repulsion of its particles takes place, so as to partially overcome their cohesive power, and render the body less dense. All bodies expand by heat,—the degree of this expansion, however, differs widely in different bodies. The expansibility of fluids is greater than that of solids, with equal degrees of heat.

All gases expand nearly equally with the same degrees of heat: this is not the case, however, with the solids and liquids. Some bodies are much better *conductors* of caloric than others:

dense bodies are generally the best conductors of caloric: the metals are better conductors than wood or glass; porous bodies conduct with less facility than dense ones. Snow is porous, and therefore a poor conductor of caloric,—this is why the ground freezes less when covered with snow, than when it is naked.

The different conducting power of bodies is illustrated by a familiar example: on a cold winter morning we find the hearthstone intensely cold to the feet, while the woolen carpet is warm: now as as they are both exposed to the same temperature, the different sensation produced must depend on the different conducting power of the two bodies, the one conducting off the heat of the body so rapidly as to produce the feeling of coldness, and the other conducting but very slightly.

By *specific* caloric is understood, that quantity which is peculiar to each body: when one body is found to possess a greater amount of caloric than another of equal weight, it is said to possess a greater *capacity for caloric.* The reason why different substances possess different capacities for caloric, is not precisely known. Bodies least dense appear generally to possess the greatest capacity for caloric,—while those more dense possess the least. Hydrogen gas, the lightest of all known bodies, is said to possess this capacity in the greatest degree.

When a piece of cold iron is hammered for a few minutes. it becomes hot: when sulphuric acid is mixed with a liquid less heavy and dense, as water or alcohol, the mixture becomes hot; when ice melts and becomes water, it absorbs heat, or becomes colder, as is shown by a thermometer. The heat which is developed in the last case, and which was before inappreciable to the senses, is called *latent heat.*

All heated bodies are constantly emitting or throwing off caloric; this is called *radiant* caloric,—because it is *radiated* in all directions like the rays of light. This effect is not produced by the gradual conduction of caloric by the air, because the same effect takes place in a vacuum, and in a direction opposite to the wind. When rays of heat fall upon any body, they are, like the rays of light, either absorbed, reflected, or transmitted. Highly polished substances reflect the heat,—while rough surfaces absorb it. The angles of incidence and reflection are equal in radiant caloric, as well as in light and sound. The color of bodies has an important influence on their radiating power: dark colors radiate better than light ones.

The *transmission* of heat through the air takes place without any obstruction, as is the case with light; but with respect to other transparent media it is different. "If a parabolic or concave mirror be taken, and its axis directed towards the sun, the rays of both heat and light will be reflected to the focus, which will exhibit a temperature sufficiently high to fuse a piece of metal, or fire a combustible body. If a plate of glass be now placed between the mirror and the sun, the effect will be but little diminished. Now let the same experiment be made with the heat and light of a common fire; both will be concentrated by reflection as before,—but on interposing the glass the heating effect of the focus will be reduced to almost nothing, while the light will not have undergone perceptible diminution.

"Thus the rays of heat coming from the sun traverse glass with great facility, which is not the case with those emanating from an ordinary red hot body." Rays of heat are not transmitted equally through different bodies of equal transparency: for example, of 100 rays falling on a crystal of rock salt, 8 were intercepted: of the same number, glass intercepted 61, and alum 91. Color also varies the power of bodies to transmit heating rays. Black and opake bodies stop the rays completely. Rays of heat from different sources differ in their properties: those proceeding from red hot copper and fluor spar, differ from those from an oil lamp or the sun. *Cold* is merely a negative condition depending on the absence of heat.

There are several *sources* of caloric, of which the *sun* is the principal, and compared with which all others are insignificant. The sun radiates heating as well as luminous rays, which reach the earth, and are partly absorbed and partly reflected. The *combustion* of bodies is another source,—electricity, galvanism, friction, condensation, animal vital action, and chemical action, are all sources of caloric. The earth is supposed to contain in its interior a vast amount of heat. The relations of heat to the growth of vegetation are important, and will be noticed in another place.

ELECTRICITY.

Electricity is a fluid or principle pervading all nature, so far as we know. The first full investigation of this extensive and interesting branch of science was made by Dr. Franklin; and although it is only a few years since, yet it has become identified with almost every branch of physical science, and has already had an immense influence on the moral and social, as well as commercial condition of the civilized world. We still know little of the nature of electricity; although many of its properties and effects are somewhat well understood, still all investigation and discovery has only tended to render its true nature and phenomena more mysterious, and its origin more questionable. We see its effects, but what it is, or whence it originates, we know not.

But for the sake of convenience, philosophers have applied certain terms to its peculiar properties: these terms in some cases indicate particular effects and conditions, and in others they may be said to be little more than names for our ignorance. Electricity is supposed to be a fluid which exists in two opposite states, viz: *positive* and *negative.* The terms *vitreous* and *resinous* have also been used to designate these two states.

The simplest manner of exciting or producing electricity is by rubbing a piece of amber or sealing wax on dry cloth, when it will be found capable of attracting light bodies, such as feathers, bits of thread, paper, &c. The body so affected is called an electric, and is said to be in a state of *electrical excitation.* The sealing wax or amber in this case is in the *positive* state, or is positively electrified, while the feather or other substance attracted to it is in the *negative* state, or is negatively electrified. It is impossible to develop one of these states or phenomena without at the same time developing the other also. After adhering to the electrical body for a few seconds it will fall off, it being charged with electricity and in the positive state like the electric: if the electric be excited again, and the feather presented to it, it will be strongly repelled and tend to fly off—this is called *electrical repulsion.*

The passage of the electric spark is instantaneous: it appears also to be confined to the surface of bodies in its passage. Bodies which allow electricity to pass over them are called *conductors:* these are *non-electrics,*—that is, they cannot be excited by friction so as to produce electricity: on the contrary, those bodies which can be electrically excited will not conduct the fluid; so that *non-conductors are electrics,* and *non-electrics* are *conductors.*

The electric spark fires gaseous mixtures, and is capable of producing intense heat: electricity also decomposes solutions of metallic oxides and salts. Some fishes, as the torpedo and electrical eel, possess an electrical apparatus within their bodies, which is capable of producing severe shocks upon other animals; and this is done, too, at the will of the fish. It has been satisfactorily settled by Prof. Matteucci, that electricity has nothing to do with the action of the nervous system of animals, and that life and all the vital functions are not dependent upon it for their existence and action. Electricity gives polarity to iron, and is supposed to be the *cause* of, or identical with magnetism.

The *polarity of the earth* is supposed to depend upon the passage of electrical currents around it. Electricity is designated according to its different states, by the terms *statical* and *dynamical*. *Statical electricity* treats of the properties of the fluid at rest or in a state of equilibrium. *Dynamical electricity* treats of the fluid in motion, or as it displays its phenomena while under experiment. The upper regions of the atmosphere are generally in a positive state; in cloudy weather, the distribution of the fluid is disturbed, and this gives rise to the phenomena of thunder and lightning. *Galvanism,* as well as magnetism, is supposed to be identical with, or a modification of, electricity.

Electricity is developed in various ways, by different kinds of apparatus which cannot be described in this place. All the forms of electricity are applied to useful purposes, to considerable extent, in the arts and sciences. It remains an unsettled problem as yet, whether electricity in any form can be made available to the growth of vegetation: its efficacy, also, in the healing art, is not as much relied upon as in former years; this, like all newly discovered remedial agents, has had its day of glory, and has, probably, by means of correct observation and careful experiment, fallen to about its proper standard.

NOTE.—The term PYROGEN has been proposed instead of Electricity: the term signifies generator of heat or fire.

CHAPTER III.

GENERAL PROPERTIES OF GASES.

Gas is an elastic fluid or air, formerly, but not now, supposed to be produced by the union of some body with caloric: most gases are inappreciable by the senses, except that of feeling,—having neither taste, color nor odor. Some have a specific gravity greater, and others less than common or atmospheric air. Several gases have been liquified by the conjoined action of cold and pressure: several have also been solidified by the conjoined action of intense cold and the pressure of from two to fifty atmospheres. The product of this experiment is in most cases an exceedingly transparent crystaline substance. Gases, like liquids, have but a slight power of conducting caloric: their conducting power is so slight as to be imperceptible, and they are therefore called non-conductors of caloric.

All gases possess a certain amount of specific caloric,—the precise quantity which they respectively contain has not been determined. Gases exist throughout nature, and may be produced by artificial means. Some of them are capable of being respired, without injury to health, while others cannot, without producing deleterious or fatal effects. Some are, in common language, supporters of combustion, while others are not. Those gases only which are necessary to be known in their relations to agriculture, will be described in this work.

OXYGEN—ITS PROPERTIES AND RELATIONS.

Oxygen is an invisible, transparent fluid, without taste or odor; respirable and necessary to organic life, with a specific gravity of 1.26, air being 1. It has the most extensive affinity of all known substances. It combines with metals, forming oxides and acids: it combines also with other gases, and is an important element in water and the atmosphere: it is usually called a supporter of combustion,—it exists in great abundance in nature, and may be obtained by chemical process from several substances,—most easily, perhaps, from black oxide of manganese. It is said that nearly one-third of the weight of all the solid matter of the globe consists of this gas. The combustion of all fires depends on the presence of oxygen,—a lighted taper burns with greatly increased brilliancy in pure oxygen gas.

No plant can vegetate without it, although no plant will long survive after being placed in this gas alone. No animal can respire for a single minute without oxygen, but when immersed in a jar of it, the vital processes are all increased until fever succeeds, and the animal dies. "According to Dr. Henry, 100 volumes of water absord only 3½ of oxygen." The combining number of oxygen is 8.

HYDROGEN—ITS PROPERTIES AND RELATIONS.

Hydrogen gas is the lightest of all known substances, being fourteen times lighter than common air,—destitute of taste, color or odor: it is combustible, but not a supporter of combustion; it is incapable of sustaining animal life, though it is destitute of poisonous properties,—an animal dies when immersed in it from want of oxygen,—the death results from its negative condition, rather than from any positive injury which is sustained by breathing the gas. It exists in nature in less abundance than carbon or oxygen, and is not known to occur in a free or uncombined state. It forms a small part of all animal and vegetable substances, and constitutes one-ninth part of the weight of water: it does not occur in combination with any of the mineral masses of the globe, except coal,—and this is itself of vegetable origin. This gas burns with a pale yellow flame,—its combustion is attended by the formation of water.

Plants do not grow in this gas, but gradually wither and die. Its specific gravity is 0.0687: 100 gallons of water absorb 1½ gallons of this gas. It is the gas used for inflating balloons. Hydrogen is readily obtained by the action of sulphuric acid on zinc or iron. It is necessary to the growth of vegetation, but not in a free or uncombined state. The combining number of hydrogen is 1.

CARBON—ITS PROPERTIES AND RELATIONS.

Carbon exists in a pure and crystaline form in the diamond; graphite, or black lead, and common charcoal, are examples of carbon of impure varieties. It constitutes a large proportion of all animal and vegetable substances: nearly all plants in a dried state, contain from 40 to 50 per cent. by weight, of carbon. This substance is of great importance in the art of culture, on account of its power of absorbing large quantities of the gases and vapors of the atmosphere,—this is especially true of charcoal, or carbon in a light and porous form. Charcoal is used for filtering impure water, which it cleanses f om decayed animal or vegetable substances, and coloring matters which are held in solution: it is used also in clarifying syrups and oils: it has the power of absorbing noxious vapors and gases, which result from the decomposition of animal and vegetable matters, and of preventing or retarding the decay of all organic substances.

The gases and moisture which are arrested and retained by carbon in the soil, are again readily yielded up to the roots of plants, during the process of growth. Several important ends are subserved by carbon in the soil: it purifies impure air and water, which would not nourish plants, but on the contrary prove destructive to their tender germs and roots: it absorbs gases from the air as before stated; prevents putrefaction (and acidity to some extent,) in the soil, and is itself an indispensable element in vegetation.

Carbonic acid is a gas or air, which results from the combustion of charcoal,—when charcoal is burned, it nearly all disappears in the form of gas, leaving only a small residue of ash behind. Carbonic-acid-gas is heavier than common air, colorless, invisible, having an agreeable pungent taste and odor, but cannot be respired without poisonous effects resulting from it. Carbonic acid may be obtained for experiment from white marble, which is a carbonate of lime, or from common limestone. The combining number of carbon is 6.

It is neither combustible nor a supporter of combustion,—a lighted taper dipt into a jar this gas is instantly extinguished; —it often exists in deep wells, mines, caverns and pits, and proves fatal to those who enter them,—the precaution should therefore always be taken to let down a lighted candle, which will determine the presence or absence of the gas. It is this gas also which proves so deleterious in ill ventilated rooms heated by coal fires. It is formed during the combustion of all wood, coal and oil fires,—it is generated by the respiration of animals and the growth and decay of vegetation: it is produced also, together with alcohol, during the fermentation of sugar. It is evolved in vast quantities from the ground in volcanic countries, and exists in combination with metallic oxides in the earth: these compounds are called carbonates, the most important of which is carbonate of lime. This gas has an acid reaction: water dissolves its own volume of it, and forms an agreeable sparkling solution: it is this gas which escapes during the effervesence of soda water and various kinds of beer.

It is apparent that the excessive accumulation of so poia gas must prove destructive to all animal and vegetable life, if some means were not provided by which it could be removed as fast as it is generated by natural causes: growing vegetables, although they could not live in this gas alone, require a constant supply of it as an element of food,—and this is just sufficient to preserve a wonderful balance in this respect throughout all nature.

According to Liebig, a healthy man expires from his lungs 5 ounces a day, or 100 pounds a year, of carbon: a horse, or cow, expires six times this amount,—or 600 pounds a year. Now if the crops of an acre of land require 2 tons of carbon in a year, (which is Johnston's estimate,) a farm of 25 acres would require, if all cultivated, 50 tons of carbon. If the family of the farm be reckoned at 5 adults, and the stock at 2 horses, 5 cattle, 40 sheep, 5 hogs, including the poultry, the amount of carbon they would all expire would be not far from 10 tons in a year. They would then supply from this source alone one-fifth of all the carbon requisite to grow the crops of the farm.

Coal which is dug from the earth and burned as fuel, adds to the carbon of the atmosphere a new portion, which had been buried in the earth, and consequently lost to vegetation for many centuries. The coal consumed annually in Great Britain, contains 14 millions of tons of carbon, which would supply this element to the crops of twenty-eight millions of acres.—[Johnston.] Decay of vegetation, when extensive, as in the peat bogs of Europe, the jungles of India, and the tropical forests of Africa and South America, furnishes immeasurable quantities of carbon.

The final result of this *eremacausis*, (slow combustion,) or slow decay, is the same as that of ordinary combustion: the immediate result, however, is different: decay furnishes much less carbon in proportion to the matter consumed than combustion; decay produces, also, light carburetted hydrogen, which combustion does not. The latter gas is changed by the electricity of the air to carbonic acid and water.

The evolution of carbon from volcanoes, and fissures in the earth in volcanic regions, is immense. In the ancient volcanic region Eifel, on the bank of the Rhine, an annual evolution takes place, according to Bischoff, of 27,000 tons of carbon. Some carbon is absorbed by the waters of seas and oceans, which is not, as far as we know, restored to the atmosphere. Vegetable matters carried away by water, deposited and embedded in beds of sand and clay, are thus prevented from decaying, and their carbon is consequently lost. These are two sources of loss of carbon: and although the balance between its production and consumption is nearly equal, still, according to Prof. Johnston, there is supposed to be a slight, permanent loss to the entire mass of our atmosphere.

NITROGEN—ITS PROPERTIES AND RELATIONS.

Nitrogen is widely diffused through nature, constituting nearly four-fifths of the atmosphere, and existing in many vegetable, and most animal substances. It is destitute of color, taste or odor, and is a little lighter than common air; it is incapable of supporting combustion or animal life,—but, like hydrogen, it has no positively poisonous properties. Water absorbs it in very small quantity: it is in fact distinguished for negative properties,—the reason why it does not sustain combustion and animal life, appears to be merely the absence of oxygen. Its use in the atmosphere seems to be only to dilute the oxygen sufficiently to render it fit for respiration.

Nitrogen combines with oxygen and forms acids and oxides. Its combining number is 14. Nitrogen may be obtained by burning phosphorus under a bell glass over water. It does not enter into the composition of any of the mineral constituents of the earth's crust, except coal, which is of vegetable origin. Nitrogen forms an important part in the growth of both animals and plants.

GASEOUS COMPOUNDS.

WATER—ITS PROPERTIES AND RELATIONS.

Pure water is transparent, colorless, tasteless, and inodorous: it is a compound of the gases oxygen and hydrogen, in the proportion of 8 parts of the former to 1 of the latter, by weight,—or by volume, 1 of oxygen to 2 of hydrogen. It boils, under ordinary circumstances, at 212° and freezes at 32°, Fah.: its greatest density is at about 40°,—at 212°, it takes the form of vapor or steam, and is thus increased to 1700 times its former bulk, and is about two-fifths lighter than common air,—it consequently rises and becomes diffused through the air.

Water evaporates at all temperatures above freezing: it is 780 times heavier than common air,—a cubic foot weighs sixty-two and a half pounds. It is the standard of specific gravity for all bodies,—its number in this respect is unity or 1.

The purest water, except that which has been distilled, falls from the clouds in the form of rain and snow at the close of a shower: all other natural waters contain various soluble and insoluble gaseous, mineral and organic matters,—among which are, carbonic acid, carbonate of lime, ammonia, salts of iron, soda, iodine, bromine, magnesia, silica, sulphur and others. Water possesses the most extensive solvent power of all known liquids: it absorbs gases from the air to a considerable amount: these are again expelled by boiling, and are altered in their proportions from those which constitute the atmosphere.

Water mixes with, or dissolves all liquids except those of an oily nature: it dissolves also most salts, many gums, coloring matters, and slowly dissolves many rocks and earths: water has a wide range of affinities for animal, vegetable and mineral elements, which it exercises without being itself decomposed. It is the most universally diffused through the three kingdoms of nature, of any substance: it enters largely into the composition of living animal bodies, and constitutes, according to Johnston, half the weight of all green or newly gathered vegetables which are cultivated for the use of man.

Without water, neither animals nor plants could exist, (with their present organization,) the earth would become a scorched and sterile waste: many compounds resulting from chemical affinities which require the presence of water, would be unknown: the varieties of climate which now exist would also to a great extent be unknown. Water in its relations to vegetable life, and also its meteorological influences, will be more particularly discussed in a subsequent part of this book.

THE ATMOSPHERE—ITS PROPERTIES AND RELATIONS.

The atmosphere which we breathe is an immense ocean of gaseous fluid: the depth of this ocean is about 45 miles, at the bottom of which we live,—or rather, it extends about 45 miles above the surface of the earth, which it entirely surrounds. It is composed of the two gases oxygen and nitrogen, in volume in the proportions of about 21 of the former to 79 of the latter in 100. It contains also, according to Sausseur, $\frac{1}{2500}$ of its bulk of carbonic acid.

The quantity of this gas is greater in cities than in the country, slightly less in the air over the seas and great lakes,—it is less over a wet than a dry soil, and by day than by night. The air is imbued with watery vapor which varies in different climates: it holds in suspension, traces of various animal and vegetable matters and ammonia. Heat and electricity also exist more or less at all times in the atmosphere. Air diffuses itself everywhere, penetrates the minutest recesses of every porous body, and presses with the almost incredible weight of 15 pounds to every square inch of the earth's surface: it is transparent, colorless, invisible, elastic, tasteless and inodorous. The two essential elements of the atmosphere, viz. oxygen and nitrogen, are not, according to Dr. Kane and others, in a state of chemical union, but only a mixture.

The specific gravity of air is about 780 times less than that of water; 100 cubic inches weigh about 31 grains. A column of air 45 miles high just balances a column of water of the same diameter, 33 feet high, or a column of mercury 29 inches high: hence water cannot be raised in a pump on the principle of atmospheric pressure, more than about 33 feet,—hence also the mercury in the barometer tube is about 29 inches high. The air expands and becomes less dense by heat; hence warm air always rises, and cold air descends: the composition of the air is everywhere nearly uniform,—its complete and beautiful adaptation to the wants of animal and vegetable life will be more apparent the more we become acquainted with its nature and laws: without it no animal or plant could exist for a single day. Its relations to vegetation more especially, will be described hereafter.

CARBONIC OXIDE.

Carbonic oxide is a colorless, inodorous gas, composed of one equivalent of carbon, united to one of oxygen: it extinguishes a lighted taper, takes fire at the same time itself, and burns with a pale blue flame, forming carbonic acid. It is lighter than common air, nearly insoluble in water, and does not support animal life. It is produced, together with carbonic acid, by the combustion of coal fires. "It is not known to occur in nature, or to minister directly to the growth of plants."

OXALIC ACID.

This is another compound of carbon and oxygen, in the proportions of two of the former to three of the latter. It is found in the interior of many plants, as the sorrel, rhubarb, bistort, gentian, chick pea, and several lichens: it is not known to contribute to their growth, but appears to be the result of a gaseous combustion consequent upon their growth. It is found combined with potash and lime in the form of salts called oxalate of potash and lime: it is one of the most important of the organic bodies.

Crystalized oxalic acid is, in transparent bodies, intensely sour, and very poisonous. This acid is not found in the soil, nor in the waters which reach the roots of plants: the simple process by which it is elaborated in the interior of plants will be described hereafter. Oxalic acid neutralizes alkalies perfectly, and forms several important salts. There exists a relation between carbonic acid, carbonic oxide and oxalic acid, which will be described under the head of vegetable physiology.

LIGHT CARBURETTED HYDROGEN.

This is a light, inflammable gas, which is formed by the decomposition of organic substances at high temperature: in warm weather it may be seen rising in bubbles from marshy places and stagnant pools, when vegetables are in process of decomposition. This gas is colorless, destitute of taste or odor, about half the weight of common air: a lighted taper is extinguished by it, while the gas ignites and burns with a pale yellow flame: animals immersed in this gas cease to breathe almost instantly. This is the gas which exists in marshes under the name of *marsh gas,*—and also in coal mines under the name of *fire damp:* violent explosions sometimes took place in coal mines by the ignition of this gas mixed with oxygen, from the miners' lamps, previous to the invention of the safety lamp by Dr. Davy. It consists of one equivalent of carbon and two of hydrogen.

This gas, together with carbonic acid, is given off during the fermentation of compost, and all large collections of vegetable matter. "It is supposed, [says Johnston,] by many, to minister to the nourishment of plants: it is, however, very sparingly soluble in water, so that in a state of solution, it cannot enter largely into the pores of the roots, even though it be abundantly present in the soil:" it probably exists in all well manured soils; "but the extent to which it really acts as food to living vegetables is entirely unknown."

NITRIC ACID—ITS PROPERTIES AND RELATIONS.

Nitric acid is a compound of one part nitrogen and five of oxygen: liquid nitric acid, when pure, is colorless, intensely sour and corrosive, heavier than water, and boils at 187° Fahrenheit. If exposed to the air, it gives off white fumes with the disengagement of part of its oxygen, becomes yellow, and is converted into nitrous acid.

"True nitric acid [says Dr. Kane] has never been isolated; that substance generally spoken of as nitric acid, is a compound of it with water; it is a nitrate of water, or, as it is popularly termed, liquid nitric acid, or aquafortis." This acid decomposes all organic substances rapidly, neutralizes the alkalies, and oxidizes the metals, for which it has a strong affinity.

This acid is not found in nature in an uncombined state; but it occurs in combination with soda, lime and potash, in the form of nitrates, in many tropical countries. In the West Indies, vast quantities of nitrate of potash (salt petre) are formed by nature: in Chili and Peru, immense beds of nitrate of soda are also found. The origin of these salts is as follows: rain water, particularly that which falls during a thunder shower, contains nitrate of ammonia, when the water comes in contact with the potash, soda and lime of the soil,—having a stronger affinity for them than for the ammonia, it unites with them and forms the salts, while the ammonia is again set free and escapes into the air. These salts are soluble in water, and are important agents in promoting the growth of cultivated plants.

AMMONIA—ITS PROPERTIES AND RELATIONS.

Ammonia is a colorless gas, having a strong, pungent odor and alkaline taste: it is composed of one proportion of nitrogen and three of hydrogen: its equivalent number then is 17. It is slightly combustible, but does not support combustion. "Ammonia is rapidly absorbed by water, which takes up 780 times its volume at 32°:" this is called water of ammonia, or *spirits of hartshorn*,—it has a specific gravity about one-tenth less than water, and boils at 120°. In its power of neutralizing acids, it ranks next to lime, being a powerful base: it forms, with the metallic salts and with acids, many compounds. Ammoniacal gas does not support respiration,—animals are speedily suffocated by it, and living plants confined in it soon wither and die. It is absorbed largely by porous bodies, such as charcoal, burnt brick, burnt clay, &c.,—charcoal is said to absorb 95 times its own bulk.

Ammonia is sufficiently caustic to destroy both animal and vegetable substances. It is remarkable that the two gases which form ammonia, having neither taste nor odor when separate, produce, when united in certain proportions, a gas so intensely strong, pungent, and acrid. Ammonia being only about three-fifths the weight of common air, it rises and mingles with the air when it is set free, unless it is retained by some substance with which it will unite and form a solid substance not volatile. The salts of ammonia are easily soluble in water.

Ammonia exists in considerable abundance in nature,—it is almost universally diffused, but does not enter as a constituent into any of the mineral masses of the earth's crust. It is found mostly in a state of combination with acids, in the form of nitrate, muriate and carbonate of ammonia. It is evolved largely by the decay of animal and vegetable matters, and does not remain long in a free state in the air, but combines with acid vapors which it meets in the atmosphere, and forms other compounds.

The salts of ammonia are decomposed by lime, magnesia, potash and soda, and the ammonia is set free in the gaseous state: the ease with which compounds of ammonia are decomposed, constitutes one of its most valuable properties, and renders it peculiarly adapted to the various offices it performs in the processes of vegetation. In the air, the soil, or the interior of plants, it is easily decomposed by electricity and the alkaline bases before named.

"The hydrogen it contains in so large quantity, [says Prof. Johnston,] is ready to separate itself from the nitrogen in the interior of the plant, and, in concert with the other organic elements introduced by the roots or the leaves, to aid in producing the different solid bodies of which the several parts of plants are made up. The nitrogen also becomes fixed in the colored petals of the flowers, in the seeds, and in other parts, of which it appears to constitute a necessary ingredient, passes off in the form of new compounds, in the insensible perspiration or odoriferous exhalations of the plant,—or returning with the downward circulation, is thrown off by the root into the soil from which it was originally derived." The transformations which actually take place in the interior of plants, is not yet perfectly understood, although many of them can be clearly explained. The agency of ammonia and its various compounds, in the promotion of vegetation, is both powerful and important,—and will be explained more fully in a subsequent chapter, as will also its formation and sources.

CHAPTER IV.

ELEMENTARY BODIES.

Elementary or *simple bodies*, are those which consist of a single substance, and cannot be decomposed, or reduced to a more simple form. They are such as have hitherto resisted all attempts at decomposing them; but still, new methods of analysis may yet enable the chemist to prove them to be of a compound nature,—and indeed this has already been the case with some which were formerly considered elementary. These simple bodies are about sixty in number, so far as yet known; but chemical analysis will doubtless make us acquainted with others. Several attempts at classification of these bodies have been made; but none, as yet, has been on all accounts unobjectionable.

One division is, into *metallic* and *non-metallic* substances: this division, although entirely arbitrary and less philosophical than some others, is still the most convenient, and sufficiently explicit for our present purpose. It is the one adopted by Doct. Fownes.

Non-Metallic Elements.

Oxygen,	Chlorine,	Silicon,
Hydrogen,	Iodine,	Boron,
Nitrogen,	Bromine,	Sulphur,
Carbon,	Fluorine,	Selenium,

Elements of Intermediate Characters.

Phosphorus, Arsenic, Tellurium.

Metals.

Antimony,
Chromium,
Vanadium,
Tungsten,
Rhodium,
Iridium,
Osmium,
Gold,
Alumnium,
Glucinum,
Zirconium,
Thorium,
Cadmium,
Copper,
Iron,
Manganese,
Lithium,
Sodium,
Pelopium,
Niobium.
Molybdenum,
Columbium,
Titanium,

Uranium,
Cerium,
Lantanum,
Platinum,
Palladium,
Yttrium,
Bismuth,
Tin,
Mercury,
Silver,
Lead,
Barium,
Strontium,
Calcium,
Magnesium,
Zinc,
Nickel,
Cobalt,
Potassium,
Ruthenium,
Erbium,
Terbium.

These sixty simple elements combine with each other in such manner as to form the innumerable compounds which make up the whole animal, vegetable and mineral kingdoms. So far as we know, all ponderable bodies in the universe are only the varied compounds of these few substances. The imponderable agents, *light, caloric, electricity, galvanism,* and *magnetism,* and the vital principle, are not well understood in their natures and composition; so that nothing can be predicated as to their relation in composition to the simple bodies. Such, only, of these bodies will be described, as are necessary to be known in their relations to Agricultural Science.

ACIDS.

Acids are chemical compounds which are capable of uniting in different proportions with alkalies, to form a third class called salts: by this union the properties of both the acids and alkalies are destroyed, or neutralized. Most acids have a sour taste,—there are, however, some exceptions: they change vegetable blues to red; they are electro-negative, and therefore have a strong affinity for the electro-positive compounds, such as alkalies, alkaline earths and oxides. Nearly all of them contain oxygen; when the oxygen is not present, it is replaced by hydrogen: they are therefore called by some writers, *oxacids* and *hydracids.*

Acids are divided again into mineral and vegetable; the mineral are, nitric, sulphuric, muriatic, &c.: the vegetable acids are very numerous,—acetic, citric and tartaric are examples. Most vegetable acids contain both oxygen and hydrogen. The mineral acids are heavier than water, exceedingly caustic and corrosive,—destroying both animal and vegetable textures. Some acids are in a fluid, and others in a dry, solid or crystaline form. They unite with water in all proportions. They absorb water from the atmosphere, if exposed, and become weaker in strength, diminished in weight, and increased in bulk.

ALKALIES.

Alkalies are a class of bodies possessing properties opposite to those of acids, having a strong affinity for, and uniting with them in different proportions, to form salts, as before stated. They are incombustible, caustic and acrid, very soluble in water, and change vegetable blues and red to green, and yellow to brown,—in fact they destroy or change the vegetable colors generally. They are divided into fixed and volatile,—the fixed alkalies are potash and soda: these do not evaporate, like ammonia, which is therefore called a volatile alkali. They have a sharp, pungent taste, destitute of acidity, and, with the exception of ammonia, have but little odor. They unite with the oils and fats, and form the well known compound, soap. There is also a class of compounds called alkaline earths, as lime, barytes, magnesia and strontium. The alkalies and alkaline earths are electro-positive in their affinities.

SALTS.

Salts constitute a numerous class of compounds, which result from the chemical union of acids and alkalies. They are of three kinds, viz: *acid, basic* and *neutral.*

Acid salts contain an excess of acid; most of them are not really acid salts, but double salts, of which one base is water; bi-carbonate of potash is an example.—[Kane.] The substance which unites with an acid to form a salt, is called a *base.*

Basic salts are those in which there is more than one equivalent of base for one of acid, as in sulphate and nitrate of copper.

Neutral salts do not manifest either acid or alkaline properties on vegetable colors,—they have neither an acid nor an alkaline taste, and generally consist of one equivalent of acid and one of base.

Double salts are formed by the union of two simple salts; in general both salts contain the same acid, but different bases. Salts usually crystalize in regular determinate forms; some being in prisms or crystals, having three, four, five, six, &c., sides, and as many angles. Most salts contain some water in a loose state of combination: this is called their *water of crystalization.* This water evaporates from some salts, and they become a dry powder,—such are called *effervescent salts:*

others absorb more water from the atmosphere, and are dissolved in it,—these are called *deliquescent salts.*

Salts may effervesce or deliquesce without destroying their peculiar qualities or the chemical union between the acid and base. Salts dissolved by water again crystalize when the water is evaporated. The crystals of some salts are very small, as in epsom salts,—in others they are large, as in chromate of potash.

ORGANIC ELEMENTS OF PLANTS.

Organic bodies possess a much greater complexity of composition, than substances of mineral origin. The organic bodies are distinguished from the inorganic by the nature of their elements: the products of the vegetable kingdom surpass in number and variety those of the mineral,—but still those of the former consist almost exclusively of six elements, viz: *carbon, oxygen, hydrogen, nitrogen, sulphur,* and *phosphorus:* of these six, carbon alone exists in all bodies of both animal and vegetable origin. Sulphur and phosphorus are met with but seldom: *iodine* and *bromine* exist in marine plants and sponges; besides these, plants contain in most cases, *iron, silicon, calcium, potassium, magnesium, manganese,* and sometimes *fluorine.* These are called the *ultimate elements* of plants,—because they are the final result of analysis, and cannot themselves be reduced to a more simple form, or separated into other elements.

These combine in such a manner as to form the various substances, such as starch, gum, sugar, and an almost endless variety of others found in plants. These latter are called *organic products,* or *immediate* or *proximate elements,* because they are more easily separated and obtained without a rigid analysis. As a general rule, bodies most complex in their number of elements and simplicity of equivalent relations, are the weakest, and least capable of resisting those disturbing forces which tend to produce decomposition, or transformation of their elements. Substances of different properties, but identical in composition, are called *isomeric bodies.*

These bodies, although containing the same ultimate elements, may be as widely different in their chemical relations as bodies which have no elements in common. Oil of turpentine and oil of citron are isomeric compounds,—each being composed of carbon 5—hydrogen 4.

LIGNINE.

The proper wood of plants, when separated by chemical means from all soluble substances, is called *lignine.* It is composed of carbon, hydrogen and oxygen,—these are its constant elements, whether it be obtained from the porous willow, dense boxwood, or the fibres of linen and cotton. The hydrogen and oxygen exist in the same proportions as in water; so that lignine is apparently only carbon and water: but distillation does not prove this to be the case.

Pure lignine is white: it undergoes no decomposition in dry air, or under water which contains no air; but by the joint action of heat and air it undergoes changes which produce another series of compounds, very different from itself. Woody fibre is arranged in cells and tubes: the walls of these cells and tubes are composed of *cellular* woody fibre, and covered by a solid substance called *incrusting matter.* It is difficult to separate the two, so as to determine by analysis the precise difference in their composition. It is evident that woody fibre constitutes the great mass of all forest trees, and also of the dried stalks and roots of most plants.

STARCH.

Starch is probably the most abundant product of vegetation, with the exception of woody fibre. It is obtained from the flower of all the grains, many roots, the pith and seeds of many other plants. Starch is obtained in the form of a fine powder, consisting of rounded, shining white particles. They are tasteless and inodorous, and when kept dry undergo no change in any length of time. Starch is insoluble in cold water or alcohol, but dissolves readily in hot water, and forms a jelly. Starch, like lignine, is composed of carbon, hydrogen and oxygen. Starch is a delicate test for the presence of iodine.

Arrowroot, sago, tapioca, inuline and *lichenine* are varieties of starch. It is frequently deposited among the woody fibres and in the inner bark of trees, as the willow, beech and pine. This is the reason, [says Prof. Johnston,] that the branch of a willow takes root so readily, and also, that the bark of trees is used in some countries as food.

GUM.

Gum arabic is a familiar example of this class of substances; the gum from peach and plumb trees is similar in constitution. Pure gum is light colored, having a sweetish taste, destitute of odor, insoluble in alcohol, soluble in water, with which it forms an adhesive mucilage. Gum is composed of carbon, hydrogen and oxygen: it exists in the seeds and other parts of many plants. *Arabine, carasine, bassorine, dextrine,* and *tragacanthine* are all varieties of gum: this, as well as starch, is highly nutricious as food.

SUGAR.

Sugar exists in many plants,—but is obtained principally from sugar cane, sugar maple, and beet root. Pure sugar is in large transparent crystals, having a pure sweet taste, destitute of odor, soluble in water, highly nutricious. Its constituent elements are carbon, hydrogen and oxygen. *Grape sugar, sugar of milk,* and *sugar of mushrooms,* are all varieties.

MUTUAL RELATIONS OF LIGNINE, STARCH, GUM AND SUGAR.

It is a remarkable fact, that these four substances, though possessing properties so entirely different, are composed of the same elements in the same proportions. This fact, so evident to the analytical chemist, is still little more comprehensible to him, after his most profound investigations, than to the most unlearned. And, although we can readily separate the elements of these bodies, we cannot combine the same elements so as to form any one of them. The formulæ below show their constitution.

Woody fibre	is	composed	of	C. 12, H. 10, O. 10.
Starch	"	"	"	C. 12, H. 10, O. 10.
Gum	"	"	"	C. 12, H. 10, O. 10.
Cane sugar	"	"	"	C. 12, H. 10, O. 10.

These four substances are capable of being transformed one into another, as woody fibre into starch, starch into sugar, gum into sugar, &c., as will be hereafter described.

GLUTEN.

Gluten exists in the flour of wheat, rye, barley and oats, from which it may be obtained by washing the paste or dough for a long time in water. It is a soft, tenacious, elastic, grayish substance, with very little taste or odor. It is nearly insoluble in water, but easily dissolved by alcohol, acids and alkalies: when moist gluten is dried at 212°; it becomes a semi-transparent, yellowish, brittle mass, resembling glue. Wheat contains more gluten than any of the other grains: it contains, according to its quality, from 8 to 35 per cent. Gluten is highly nutricious: it is composed of carbon, hydrogen, oxygen and nitrogen.

ALBUMEN.

Albumen is a gelantinous, colorless substance, without taste or smell, dissolved by acids and alkalies, but insoluble in alcohol and water. Albumen resembles the white of eggs, which is animal albumen; it abounds in the juices of many plants, as cabbage, turnips, &c.: its composition is identical with that of gluten, which is as follows:

Carbon,	54.76
Hydrogen,	7.06
Oxygen,	20.06
Nitrogen,	18.12
	100

When exposed to air and moisture it undergoes decomposition, which is attended by the formation of vinegar and ammonia. It possesses highly nutrient properties.

WAX.

Wax is found in many plants: beeswax may be taken as the type of this class of bodies. It is insoluble in water or cold alcohol, but dissolved by boiling alcohol, which separates it into two proximate principles, viz: *cerine* and *myricine.* Beeswax melts at 144°, and when freed from its yellow coloring matter, has a white crystaline appearance, Cerine, boiled with a solution of potash, forms soap. Wax is supposed to be derived from the oils of plants.

RESIN.

Resin is obtained from the pitch of various of the coniferous family, such as the pine, hemlock, fir, &c. Resin is highly inflammable, insoluble in water, but readily dissolved by alcohol and essential oils: the principal resins are, common rosin, copal, mastic and elemi. Common rosin is what remains after the distillation of pitch to obtain spirits of turpentine.

CAMPHOR.

Camphor is a gum-like, white, brittle, semi-transparent substance, having a strong peculiar odor and an acrid bitter taste.

It exists in several plants, but is found in most abundance in the camphor tree. It is highly inflammable, and resembles in some respects the resins: it is nearly insoluble in water, but dissolved by alcohol and oils.

CAOUTCHOUC.

Caoutchouc, or *India Rubber*, is the product of several trees in tropical countries, from which it exudes in the form of a milky juice which hardens by contact with the air. It is insoluble in water or alcohol, and dissolves but imperfectly in ether; its proper solvent is volatile oils: oil of turpentine dissolves it, but it dries imperfectly afterwards. At a temperature a little above that of boiling water it melts and never resumes its elasticity: in its properties, it possesses considerable resemblance to the resins: it may be converted into a volatile oil by distillation.

FIXED OILS.

Oils are divided into two classes, viz: *fixed* and *volatile*: the former are capable of being distilled without decomposition,—the latter are not. The animal and vegetable oils agree in their properties very nearly in every respect. The fixed oils are obtained by pressure, from the seeds of various plants, as the castor bean, flax seed, &c.

They have little taste or odor, are lighter than water, congeal at a lower temperature, and require a higher heat than that of boiling water to evaporate them. They are highly nutricious, and combine with soda to form soap: by contact with air they become rancid and gummy: they are all insoluble in water, and, with the exception of castor oil, but slightly so in alcohol: they dissolve easily in ether and the volatile oils.

VOLATILE OILS.

Volatile or essential oils are numerous in the vegetable kingdom, and give to plants their peculiar odors: they are obtained by distillation. Most of them are lighter than water, highly combustible, and dissolve in alcohol to form essences: when pure, they are colorless, and evaporate from paper without leaving a greasy stain, as fixed oils do: they do not form soap with alkalies.

VEGETABLE ACIDS.

Acids are numerous in the vegetable kingdom, and possess much interest and importance; but the limits of this book will not admit of a detailed account of them: they constitute but a small part of the plants from which they are derived. The most important are the *acetic, oxalic, tartaric, citric* and *malic* acids. The general properties of acids have already been described.

VEGETABLE ALKALIES.

Alkalies exist in all plants, and always in the form of salts, or in combination with an acid. *Potash, lime* and *soda,* although found in plants in greater abundance than the others, are *not* vegetable alkalies: the true vegetable alkalies are, *morphia, quinia, strychnia,* &c.

Metallic oxides and earths found in plants have already been named, and their properties will be described in another chapter. The few organic proximate elements of plants which have been briefly described, are but a comparatively small part of the whole number: only such as possess most interest, and are most common and necessary to be understood, have been selected.

DIASTASE.

Diastase is a white, tasteless powder, formed during the process of malting barley, and also during the germination of plants. The properties of diastase are not well understood,—it is supposed to be the first product of the putrefactive fermentation of vegetable gluten and albumen.

EXTRACTIVE MATTER.

Extractive matter (apotheme) exists in vegetables, and may be obtained by steeping them in hot water, and then evaporating the water, when a brown powder will remain, which is but slightly soluble in water or alcohol, but soluble in alkalies. Its nature is not well understood; Dr. Kane, however, supposes it may be identical with ulmic or humic acid. It is not nutricious.

TANNIN.

Tannin exists in the bark of most trees, but most abundantly in the bark of the oak, horse chestnut and hemlock. It is an astringent brownish powder, soluble in alcohol and water. It has an astringent taste and is destitute of odor: it combines with animal gelatine and forms an insoluble precipitate; hence by soaking the skins of animals in a solution containing tannin, it is converted into leather, which is no longer subject to putrefaction. It is composed of carbon, hydrogen and oxygen: it is not nutricious: it precipitates most metallic solutions, and is hence used in practical chemistry as a re-agent.

COLORING MATTER.

The matter which constitutes the basis of vegetable colors is found in most plants. "The organic coloring principles, [says Dr. Fownes,] with the exception of one red dye, cochineal, are all of vegetable origin." The art of coloring is based upon the affinity which exists between the coloring matter and the fibres of the different fabrics to be colored. This is stronger in woolen than in cotton and linen; hence in dyeing the two latter a third substance, called a *mordant*, is used, which strengthens their affinity: for this purpose, salts of alumina, iron and tin are used.

The coloring principle of vegetable blues is *indigo:* that of madder red is *alizarine:* of madder yellow, *xanthine*: the green color of plants depends upon a substance called *chloro-*

phylle. The coloring principle of logwood is *hæmatoxyline:* *carmine* is a beautiful pink color derived from the cochineal insect: several substances produce yellow and brown.

Nearly all vegetable colors are destroyed by the action of solar light,—and all of them, without exception, by the action of chlorine gas: acids and alkalies destroy or change them. No coloring principle has yet been found in plants, capable of being transferred to other bodies so as to produce a green: greens are therefore produced by the action of blues upon a base of yellow. *Substantive colors* are those which combine directly with the fibres of cloth without the intervention of a mordant: *adjective colors* require the assistance of a mordant to make them permanent.

INORGANIC ELEMENTS OF PLANTS.

Besides the organic elements which enter into the composition of plants, and which, as before stated, are themselves in most cases composed of the four principal elements, carbon, oxygen, hydrogen and nitrogen,—there are several inorganic substances, which are constantly present in all plants, and in about the same relative proportions in the same plant in all cases. These are in combination with the gases and with one another. *Chlorine, iodine, sulphur, phosphorus, potassium, sodium, calcium, magnesium, aluminum, silicon, iron* and *manganese.*

CHLORINE.

Chlorine is a yellowish green gas, having a pungent, suffocating odor; it is soluble in water, extinguishes a lighted taper, has a specific gravity of 2.47, and when submitted to the pressure of four atmospheres, is condensed into a limpid, yellow liquid. This gas is a supporter of combustion, but not of animal life: a piece of phosphorus, gold leaf, potassium or sodium, introduced into it, inflame and burn spontaneously. Chlorine has but little affinity for oxygen, its chemical preferences being principally hydrogen and the metals: it is not found in an uncombined state in nature. The most characteristic property of this gas is its bleaching power; it decomposes readily the most permanent organic coloring principles; the presence of water is necessary to develop the bleaching properties of chlorine. This gas is a highly disinfecting agent. Common salt is a compound of chlorine and sodium.

IODINE.

Iodine is a solid substance, in shining lead-colored scales. It is volatilized or converted into vapor by a moderate heat,—the vapor has a beautiful violet color, and an odor resembling chlorine. It is soluble in water, and more perfectly so in alcohol. It is obtained from the ashes of marine plants, but has not as yet been detected in any of the plants cultivated for food. Both plants and animals confined in the vapor of iodine soon perish.

SULPHUR.

Sulphur exists in considerable abundance in nature; the most common source of the sulphur of commerce is volcanic action: it is sublimed and thrown out in large quantities from the earth,—it exists also in natural waters. It is a yellowish green powder, having little taste or smell,—it is but slightly soluble in water. When heated it exhales white fumes of an intensely suffocating odor,—these fumes are called *sulphurous acid*. This gas is destructive to both animal and vegetable life: it possesses bleaching properties. There are several compounds of sulphur which are essential to the growth of vegetation.

PHOSPHORUS.

Phosphorus is a solid substance, having the consistence of wax, and of a pale yellow color: when exposed to the air, it takes fire spontaneously and burns with a pale blue flame, scarcely visible except in the dark. When heated, however, it takes fire and burns with a brilliant flame and intense light, with the evolution of dense white fumes.

It is not found in nature in an uncombined state, "and is not known [says Johnston,] to be susceptible of any useful application in practical agriculture." *Phosphoric acid* results from the combination of the fumes of burning phosphorus with the oxygen of the atmosphere. It has the characteristic properties of acids, and unites with lime, soda and potash, to form *phosphates.* This acid is not found in nature in a free state,—but the compounds of phosphorus are extensively diffused throughout nature, and are essential to the growth of all cultivated plants.

CATALOGUE OF THE COMPOUNDS DERIVED FROM THE INORGANIC ELEMENTS OF PLANTS.

Sulphurous acid,	Alumina,
Sulphuric "	Silica,
Phosphoric "	Protoxide of Iron,
Potash,	Peroxide "
Soda,	Protoxide of Magnesia,
Lime,	Sesquioxide "
Magnesia,	Peroxide "
Chloride of Potassium,	Sulphuret of Potassium,
" Sodium,	" Sodium,
" Calcium,	" Calcium,
" Magnesium,	" Iron,
First Chloride of Iron,	Bi-sulphuret "
Second " " "	Carbonate of Potash,
Carbonate of Soda,	Bi-carbonate "
Bi-carbonate "	Sulphate "
Nitrate "	Nitrate "
Sulphate "	Binoxalate "
Phosphate "	Bitartrate "
Bi-phosphate "	Phosphate "

Carbonate of Lime,
Sulphate "
Nitrate "
Phosphate "
Bi-phosphate "
Silicate of Potash,
Bi-silicate "
Silicate of Soda,
Bi-silicate "
Silicate of Lime,
" Magnesia,
Carbonate of Magnesia,
Sulphate "
Bi-phosphate of Potash,
Carbonate of Magnesia,
Bi-carbonate "
Sulphate "
Nitrate "
Phosphate "
Sulphate of Alumina,
Phosphate "
Silicate "
Carbonate of Iron,
Sulphate "

These are not all the compounds found in plants; but they are those which exist in most plants, and which are more or less essential, in some quantity, to the healthy growth and maturity of the various parts of the vegetable organization.

CHAPTER V.

FERMENTATION.

Fermentation is a peculiar decomposition or transformation of the elements of a complex organic substance, by the agency of some external disturbing force different from ordinary chemical attraction, as heat, air, or contact with some other body similarly affected.

Liebig.

THE compounds which are capable of fermentation, or any similar change, are those in which a weak affinity or equilibrium exists, and is consequently easily disturbed and overcome, by several different agencies, such as heat, acids, oxygen, chlorine, &c. If we add to a solution of sugar and water a small quantity of any organic substance which is itself in the act of slow decomposition, the sugar becomes affected in the same way, and is changed to carbonic acid and alcohol.

This is called *vinous fermentation:* another form of vinous fermentation is that which takes place in the transformation of *must* into wine: when the expressed juice of the grape is exposed to a temperature of about 70° F., its own temperature is raised, carbonic acid is given off, a scum rises to the surface, and a sediment subsides to the bottom, and the must is changed to wine. This is the simplest case of fermentation: yeast is peculiarly effective in producing this kind of fermation. *Yeast* is the product of the vegetable gluten or albumen in fermentation. The fermenting power of yeast is destroyed by boiling, by alcohol, by many salts and acids, and generally by all those agencies which render albumen and gluten insoluble.

Besides yeast, there are several vegetable substances, as gluten, albumen, caseine and fibrine, which, when in a state of decomposition, act as ferments on a solution of sugar. The same effect is produced, also, by animal gluten, albumen, flesh and blood, after putrefaction has commenced. When wine and cider are exposed to the air at a certain temperature, a second fermentation, called the *acetous*, takes place, and they are changed to vinegar: during this change oxygen is absorbed from the air, and carbonic acid is evolved: "but the apparent cause of the formation of vinegar is the abstraction of hydrogen from the alcohol, so as to leave the remaining elements in such proportions as to constitute acetic acid. The presence of nitrogen seems to be necessary to the composition of all ferments. The precise nature of the changes which take place during fermentation are not yet precisely understood or explained.

"We can offer no other explanation of these facts of fermentation than this, that when a body in a state of progressive change, the particles of which are in a state of motion, is placed in contact with another body, the particles of which are in a state of unstable equilibirum, the amount of motion mechanically communicated to the particles of the latter from those of the former is sufficient to overturn the existing equilibrium, and by the formation of a new compound, establish a new equiblirum more stable under the given circumstances."

[Turner.

METAMORPHOSIS OF ORGANIC ELEMENTS.

There are certain organic compounds which, from the complexity of their constitution and consequent weakness of affinity, are peculiarly disposed to decomposition and change of elementary form. Among these are starch, gum, sugar and lignine, the first three of which are composed of the same elements in the same proportions.

These are disposed to change of elementary form whenever the balance of opposing forces is destroyed: that is, whenever by the agency of some external disturbing force, as heat, air or water, the affinity which holds these elements together is overcome, the elements are separated entirely, or one element is replaced by another; and thus lignine is changed into starch, starch into sugar, &c.

This intimate relation of composition among these substances renders it plain that they may all occur together in the same plant, and that when one occasionally disappears from the plant, it may be replaced entirely or in part by another; and this is really the case. *Lignine* or *woody fibre* may be changed to starch by boiling sawdust in water so as to separate all soluble matters, then drying it in an oven and fermenting with yeast. In this way the author has made bread of beech wood, which was but little inferior to that made from unbolted wheat flour.

Woody fibre may be transformed to starch, also, by the action of sulphuric acid or caustic potash.

Starch, when gradually heated to a temperature not exceeding 300° F., acquires a brownish tint, and is changed to gum. Starch may be changed to gum by dissolving it in hot water, and allowing it to remain in a cold place for a few months; or it may be changed more rapidly by boiling it in water for a length of time. By the action of sulphuric acid, also, starch may be changed to gum, and this gum again into grape sugar.

Gum arabic may be changed to sugar by the agency of chalk and sulphuric acid.—[Berzelius.

Cane sugar which is crystalized, if heated to a temperature of 360° F., gives off two atoms of water and is changed to *caramel:* this is an uncrystallizable sugar, containing one proportion of oxygen and one of hydrogen less than cane sugar. Cane sugar may be changed to grape sugar by digesting it in dilute sulphuric acid at a gentle heat. The formula for these two varieties of sugar is as follows:

Cane Sugar.		*Dry Grape Sugar.*	
Carbon,	12,	Carbon,	12,
Hydrogen,	10,	Hydrogen,	12,
Oxygen,	10.	Oxygen,	12.

From the fact that we can produce these metamorphoses at pleasure, it is easy to conceive that they may take place even more readily and perfectly in the vegetable organization, than by the comparatively clumsy operations of the chemical laboratory. This is one of an infinite number of the beautiful processes of nature which modern chemistry has discovered.

PART II.

GEOLOGY.

CHAPTER I.

Geology investigates the nature, composition, origin, structure, and arrangement of the materials of which the earth is composed. Geology may be divided into three parts, viz: 1. *Chemical Geology*, which investigates the chemical nature and composition of the various materials of which the earth is made up. 2. *Mechanical Geology*, which treats of the arrangement, structure and relative position of these various materials. 3. *Historical Geology*, which treats of their relative ages and origin, and the changes which they are undergoing.*

Every part of the earth, including air and water, except undecomposed animal or vegetable matters, is regarded as *mineral.*

The term *rock*, in geological language, includes besides the solid parts of the globe, the loose materials, such as sand,

* This division is proposed by the author, and is, like all the others which have been proposed, imperfect, and, in some respects, objectionable. It has the advantage of being plain and convenient: such a division, however, whether perfect or imperfect, is not indispensable to the successful study of Geology.

gravel, clay, soils, &c., which constitue a part of its crust. "Taken as a whole, the earth is about five times heavier than water, and two and a half times heavier than common rocks." The density of the earth increases from the surface towards the centre. The surface of the earth beneath the ocean, as well as the dry land, is elevated into hills, with plains and vallies intervening. The mean depth of the ocean is estimated at between two and three miles; from the phenomena of tides, the Atlantic, in its middle part, is supposed to be over nine miles deep.

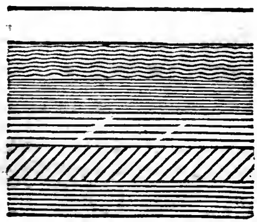
DEFINITION OF TERMS.

Rocks are divided into two great classes, viz: *stratified* and *unstratified.*

Stratification consists of the division of a rock into regular parallel planes or leaves, varying in thickness from that of thin paper, to several yards. Strata are often tortuous and variable in thickness in different parts of the same lamina or layer; "nevertheless, the fundamental idea of stratification, is that of parallelism in the layers." "The term stratum is sometimes employed to designate the whole mass of a rock, while its parallel subdivisions are called beds, or layers." So, also, of sand, clay, gravel, &c.

The term *bed* is used to designate a layer or mass of rock more or less irregular, lenticular or wedge shaped, lying between the layers of another rock,—such as beds of coal, gypsum or iron.

Fig. 1.



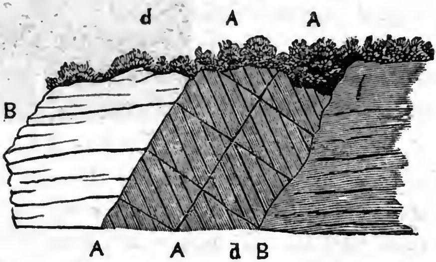
- - - - Without lamina.
- - - - With waved lamina.
- - - - Finely laminated.
- - - - Coarsely laminated.
- - - - Obliquely laminated.
- - - - Parallel lamina.

"A *seam* is a thin layer of rock that separates the beds or strata of another rock, as a seam of coal, limestone, &c."

A *joint* is a separation of rocks, both stratified and unstratified, into masses of some determinate shape: joints are more or less parallel, and usually cross the beds obliquely.

Cleavage planes are divisions in rocks, which do not coincide with those of stratification, lamination or joints. They are supposed to result from a crystaline arrangement of the particles of the rock.

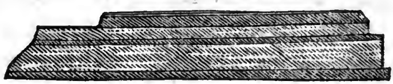
Fig 2 Cleavage Planes.



[Fig. 2 exhibits the planes of stratification, B, B,—the joints, A, A, A, A, and the slaty cleavage, d, d.]

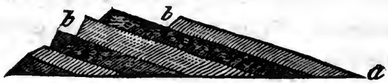
Horizontal strata are those which have little or no inclination,—but lie parallel with the horizon: this position, however, is rare, almost all strata being more or less inclined.

Fig. 3. Horizontal Strata.



The *Dip* of strata signifies the angle which they form with the horizon.

Fig. 4. Dip and Outcrop.



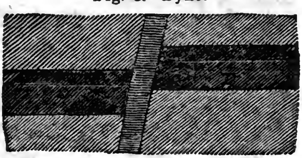
Outcrop.—When strata are uncovered above the surface, or protrude from the side of a hill so as to be visible, they are said to *crop out.*

An *Escarpment* is formed when strata terminate abruptly, so as to form a precipice.

A *Fault* in a rock is the dislocation of strata, so that their continuity is destroyed, and a series of strata on one or both sides of the fracture are forced from their original position, and raised one above another, or moved laterally. Faults are generally filled with clay, sand and fragments of other rocks.

A *Gorge* is a wide and open fissure or fault: when still wider, with sloping sides and rounded at the bottom, it is called a *valley*.

Fig. 5. Dyke.



A *Dyke* is a mass or wall of rock interposed between the ends of a dislocation, so as to break their continutity: dykes rarely send off branches.

Veins are portions of rocks smaller than dykes, proceeding from some large mass, and ramifying through a rock of a different kind. Metallic veins were originally melted metals, which were injected into the fissures and crevices of rocks by some subterranean force.

Fossil.—This term includes those petrified remains of plants and animals which are found in alluvium, or imbedded in solid rock, and constituting part of its structure.

Formations.—The term formation is used to designate a group of rocks having some character in common,—either in relation to age, origin or composition. Every formation consists of several varieties of rock, all agreeing in certain qualities, and occupying such relative situations as to indicate that they were formed during the same period and under similar circumstances. Thus we speak of graywacke formation, gneiss formation, coal formation, &c.

CLASSIFICATION OF ROCKS.

Many different classifications of rocks have been proposed, none of which is entirely unexceptionable: the present state of Geological science will admit of our adopting any one of them, without the risk of incurring much inaccuracy. It is not designed in this treatise to give a full classification of all the rocks, with a detailed description of their characters, but only the outlines of classification, and a brief description of such as are deemed most important to our present purpose.

Notwithstanding the apparent discrepancies among the systems of classification, "in all the essential principles, geologists are nearly agreed: they all admit one class to be stratified and another unstratified:—one portion of the stratified rocks to be fossiliferous and another portion not fossiliferous: and they generally agree also as to the extent of the different distinct formations. Now these three principles are all that are essential for classification; and some of the best geologists limit themselves to these."—[Hitchcock.]

One very common and natural classification of rocks is, into two great families, viz: *stratified* and *unstratified*. We shall give the outlines of two others, viz: the improved Wernerian and that of Mr. Lyell.

IMPROVED WERNERIAN CLASSIFICATION.

ALLUVIAL.	*Alluvium,* *Drift.*
TERTIARY.	*Tertiary strata.*
SECONDARY.	*Chalk,* *Green sand,* *Wealden,* *Oolitic system,* *Lias,* *New red sandstone,* *Coal formation,* *Carboniferous limestone,* *Old red sandstone.*
TRANSITION.	*Silurian system,* *Graywacke system.*

PRIMARY.	*Clay slate,* *Quartz rock,* *Hornblende slate,* *Talcose slate,* *Primary limestone,* *Serpentine,* *Mica slate,* *Gneiss.*

Alluvium.—If we commence at the surface of a soil which has been formed by the successive deposits of annual floods, or the freshets of rivers, and descend to the lowest class of rocks, viz,—the primary,—we shall pass through the different classes of rocks in the following order. The first few feet, usually less than one hundred, is composed of vegetable and earthy matters, loam, sand and fine gravel, deposited in horizontal beds.

Drift.—The second formation is made up of coarse and fine sand, gravel, and sometimes clay, containing rounded masses of rock called boulders. This mixture is often horizontally stratified.

Tertiary.—The third series is composed of clay, sand, gravel and marl, with occasional beds of quartzose and calcareous rock, which have been deposited from water in a quiet state. This series also contains many organic remains: the strata are usually horizontal, but sometimes they have a small dip.

Secondary.—The next series below the tertiary is composed mostly of solid rocks: these rocks are made up mainly of sand, clay and pebbles cemented together: these are interstratified by organic remains and several varieties of limestone,—they usually dip at various angles. The older fossiliferous rocks included in this series are sometimes called *transition rocks.*

Primary—Transition.—This class includes both stratified and unstratified crystaline rocks, which are destitute of organic remains. The unstratified rocks lie below the stratified ones wherever they have been found: hence it is inferred that the interior of the globe consists of unstratified crystaline rocks.

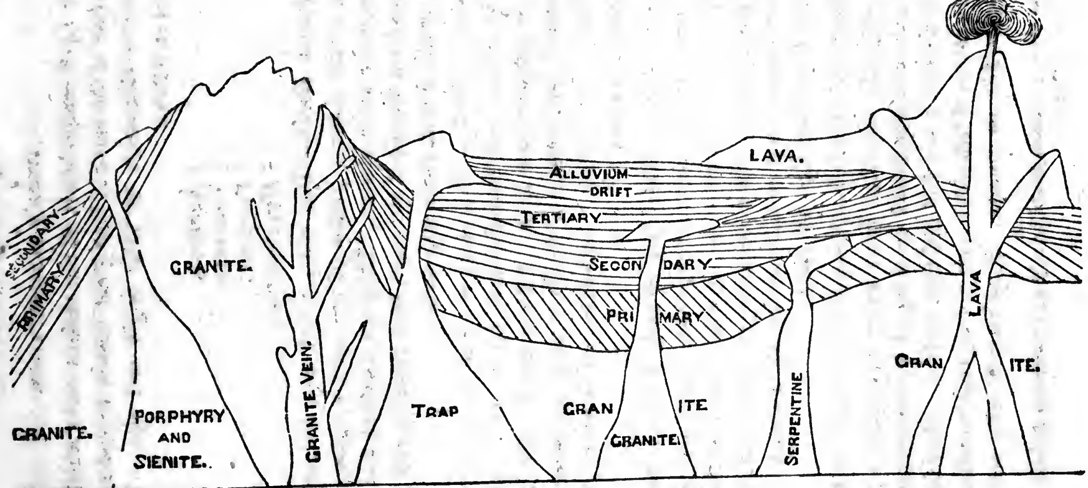


Fig. 6. Ideal Section of the Earth's Crust.

LYELL'S CLASSIFICATION.

Mr. Lyell comprehends all the various rocks which compose the crust of the earth in four great classes, depending for their distinctive characters on their origin and age. These are named as follows.

- Aqueous,
- Volcanic,
- Plutonic,
- Metamorphic.

Aqueous Rocks.—This class, called also, the sedimentary rocks, covers a larger portion of the earth's surface than any of the other three classes. They are stratified, and supposed to have been deposited by water, both running and quiescent: they contain fossils, shells and coals.

Volcanic Rocks.—This class of rocks has been produced, both in ancient and modern times, by the action of volcanic fires or subterranean heat. "They are for the most part unstratified, and devoid of fossils:" they are more partially distributed than aqueous formations, at least in respect to horizontal extension.

Plutonic Rocks.—This class of rocks has been formed, "at great depths in the earth, and they have cooled and crystalized slowly, under enormous pressure, where the contained gases could not expand." They are more crystaline than the others, have no cavities, and contain no organic remains. They lie below, and are older than all others.

*Metamorphic Rocks.**—These rocks, according to Mr. Lyell, were originally deposited from water in regular strata, and afterwards metamorphosed or changed by subterranean heat, so as to assume a new and different texture. They contain no pebbles, pieces of imbedded rock, nor organic remains, and are often crystaline, as granite. They vary in color and compo-

* This class is considered as merely a hypothetical division by many of the best Geologists.

sition. The degree of heat which produced the change in those rocks was less intense than that which produced the plutonic class, and was doubtless assisted by gaseous agency.

We have thus given a brief outline of two systems of classification, without, however, giving the reasons in favor of the propriety of any theory or classification. Our limits will not admit of a subdivision of the classes into orders, genera and species,—much other useful matter must also be excluded. A few of the most important rocks and the metalloids have been described, being thought indispensable to a proper understanding of the principles of geology and the constitution of soils.

CHAPTER II.

GRANITE.

Granite is a compound of three minerals, viz: quartz, feldspar and mica: the different ingredients are sometimes in coarse crystaline fragments, and in other cases so fine as to be scarcely distinguishable by the naked eye. Granite is most usually of a whitish or flesh color,—it has, however, other tints. Feldspar predominates in the composition of granite, while the mica is in the smallest quantity. "These three minerals are united in what is termed *confused crystallization:* that is, there is no regular arrangement of the crystals in granite as in gneiss." The coarse grained granites contain the most interesting specimens of simple minerals, while the finer kinds are best for architectural purposes.

Granite often preserves a uniform character through a great extent of country, forming rounded hills: it is sometimes, though not generally, subdivided by fissures into masses of a cuboidal and columnar form. Where it is naked at the surface, and exposed to atmospheric changes and action, it is in a crumbling state, and covered with a scanty vegetation. It is remarked by Lyell, that all granitic rocks are frequently observed to contain metals, at or near their junction with stratified rocks.

Granite is supposed to be the oldest, most abundant and important of all the unstratified rocks. There are several varieties of granite, viz: *graphic granite, syenitic granite, talcose granite, porphyritic granite, eurite* and *pegmatite:* these varieties have various proportions of each element, and also various colors and crystaline arrangement.

SYENITE.

Syenite is composed of quartz, feldspar and hornblende: it is sometimes called *syenitic granite,*—it has received this name from the ancient quarries at Syene in Egypt. It has the appearance of granite, but its composition is different, hornblende being substituted for the mica in granite. Syenite, according to Lyell, frequently loses its quartz and passes insensibly into *syenitic greenstone.*

PORPHYRY.

Rocks of a homogeneous, compact structure, containing some other crystaline mineral, of the same age with the base, are called porphyry. The base, or principal mass of the rock, may be greenstone, claystone, basalt, or other rock containing crystals of feldspar, augite, olivine, &c.

"True classical porphyry, [says Dr. Hitchcock,] such as was most commonly employed by the ancients, has a base of compact feldspar, with embedded crystals of feldspar." The term porphyry is indefinite, and does not belong to any particular rock. The term is of Greek origin, and signifies purple,—but this rock is of a variety of colors, and is the hardest and most durable of all rocks.

GREENSTONE.

This is a granular rock composed of feldspar and hornblende; the felsdpar is imperfectly crystalized: greenstone sometimes contains augite and iron also. The hornblende predominates in quantity over the other ingredients.

TRACHYTE.

Trachyte is a porphyritic rock of a grayish or whitish color, composed principally of glassy feldspar, containing also crystals of feldspar, mica, hornblende, and sometimes iron. It is rough and harsh to the touch,—hence its name from the Greek word *trachus*, (rough:) it occurs in vast quantities in Europe and South America, in volcanic regions, but is not found in the United States.

BASALT.

"Basalt consists of an intimate mixture of augite, felspar and iron, to which a mineral of an olive green color called *olivine*, is often superadded in distinct grains or nondular masses." The iron is usually magnetic, and is sometimes accompanied by the metal titanium, hence the name, "titaniferous iron." Augite is the predominant element in this rock: basatt presses insensibly into most other varieties of trap rock. True basalt does not occur in the United States.

AMYGDALOID.

Any rock containing almond shaped pieces of some other mineral, as quartz, chalcedony, agate, calcareous spar, or zeolite, may be denominated amygdaloid: the base may be wacke, basalt, greenstone, or any other trap rock. Some amygdaloid rocks have the almond shaped cells or cavities, which are empty, and glazed on their sides by a glassy coating, showing their igneous origin.

SERPENTINE.

This is a greenish colored rock, containing, according to Dr. Hitchcock, 40 per cent. of magnesia,—it is a hydrated silicate of magnesia. Serpentine sometimes contains diallage, steatite, talc, and some iron. It is classed by most authors among unstratified rocks. Comparatively it is not a rock of great extent: it is often associated with talcose slate.

LAVA.

Under the term lava, are embraced all the varieties of melted matter thrown out by volcanoes: these are composed almost entirely of feldspar and augite. Some lavas are porphrytic, and contain imperfect crystals, "derived from some older rocks, in which the crystals pre-existed, but were not melted, as being more infusible in their nature."

When lava is cooled in the open air, it is light, porous and spongy, and floats on water, as is the case with pumice stone; but when cooled under great pressure, at considerable depths below the surface, solid rock is the result.

There are several varieties of lava, varying in composition, and also of different colors, as gray, whitish, greenish and dark: fragments of granite and other rocks,—several metals and gases, water, sulphur, mud, glass, and various salts and acids, are ejected from the craters of active volcanoes.

GNEISS.

Gneiss is composed of quartz, feldspar and mica, and some specimens contain hornblende. This rock is essentially the same as granite, except it is stratified. The laminated structure becomes obscure where the gneiss passes into granite: its stratification is remarkably regular in some specimens, and in others tortuous and irregular. This rock is said to be very extensive in the United States, particularly in New England.

QUARTZ.

This rock is composed either of an aggregate of fine grains or crystals compacted together, or of a solid homogeneous mass of quartz, sometimes containing feldspar, mica, hornblende, talc or clay slate. "In these compound varieties, [says Hitchcock,] the stratification is remarkably regular; but in pure granular quartz, it is often difficult to discover the planes of stratification."

It is alternated or interstratified with all the primary rocks, in which case its structure is regular. Some quartz is capable of sustaining a powerful heat without cracking or other change,—hence it makes an excellent fire stone.

HORNBLENDE SLATE.

Hornblende predominates in this rock, over the various quantities of quartz, feldspar and mica which it sometimes contains. When it contains much feldspar, it is not slaty, but resembles greenstone. It is of a dark color, commonly associated with, and passes insensibly into clay slate, mica slate and gneiss.

CLAY SLATE.

This rock is composed mostly of fine clay, and is usually more or less dark and shining from the mixture of chlorite and black lead which it contains. "It may [says Lyell,] consist of the ingredients of gneiss, or of an extremely fine mixture of mica and quartz, or talc and quartz." It passes insensibly into mica slate, talcose slate, or hornblende slate: on the other hand it passes into unconsolidated clay.

Clay slate is the kind used for roofing: it varies in color according to its composition, from greenish or bluish gray to lead color. This rock, as well as the following, is used for whetstones: the best hones are compact feldspar, and are erroneously supposed to be petrified wood.

MICA SLATE.

This rock is a compound of quartz and mica, the mica being in the greatest quantity. This is one of the most common and abundant of the stratified rocks. It sometimes contains beautiful twelve-sided crystals of garnet in considerable abundance: beds of pure quartz also occur in this rock.

PRIMARY LIMESTONE.

This rock is sometimes in thick beds of white, bluish, greenish or gray granular marble, such as is used in sculpture: it sometimes contains, mica, quartz, hornblende, feldspar and talc. It is both stratified and unstratified; sometimes being in thick beds without any marks of mechanical arrangement, and at others it is in laminated leaves or scales like slate, of various thickness.

TALCOSE SLATE.

Talc is the principal ingredient in this variety of slate,—it is sometimes in a pure state and sometimes mixed with quartz, feldspar, mica, hornblende or limestone: it is a softish stone, valuable for building purposes. There are several varieties.

Composition of Feldspar.

Silica,	65.21
Alumina,	18.13
Potash,	16.66
	100.00

Composition of Basaltic Hornblende.

Silica,	42.24
Alumina,	13.92
Lime,	12.24
Magnesia,	13.74
Protoxide of Iron,	14.59
Oxide of Manganese,	0.33
	97.06

Composition of Mica.

Silica,	46.10
Alumina,	31.60
Protoxide of Iron,	8.65
Potash,	8.39
Oxide of Magnesia,	1.40
Fluoric Acid,	1.12
Water,	1.00
	98.26

CHALK.

Chalk is similar in composition to carbonate of lime, viz:

carbonic acid, 44,—lime, 56,—100. It is a pulverizable rock, of several varieties, which have resulted from the impurities which were deposited with it. The chalk beds contain great quantities of flint, which is dispersed through them in small masses. Chalk also contains organic remains: it is a durable building stone, and is used for docks, &c.; some ancient buildings are of chalk: no chalk has been found in America.

ROCK SALT.

This cannot be considered a rock, but yet it occurs in vast beds, and in connection with rocks, at great depths in the earth. In its pure form it is a transparent crystaline salt, having the appearance of flint glass: the impure specimens are reddish or bluish, and mixed with sulphate of soda and muriate of magnesia. Its origin is not exactly known; it is supposed, however, to have resulted from the evaporation of sea water. It is found in Spain, Poland, Hungary, Germany, and in some parts of Asia and America.

COAL.

Mineral or fossil coal is of several varieties, differing in density and weight, and of a dark color, varying from brown to jet black. It is composed of carbon and bitumen, and usually contains some other matters. Coal is undoubtedly of vegetable origin: as evidence of this, the organic structure of coal can be seen in some specimens so distinctly that about three hundred species of plants have been discovered in the various kinds. It contains also many species of fossil animals.

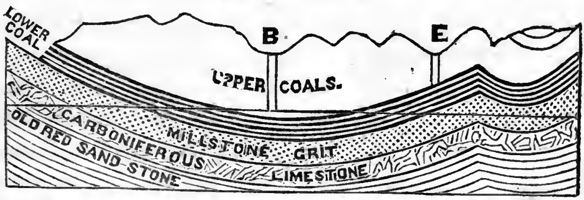
Coal beds vary in thickness, from a few feet to three thousand or more,—and are often several miles in length. The manner in which such immense masses of vegetable matter have accumulated during the lapse of ages, may be conceived by reference to a single example.

"According to Bringier, the quantity of timber which drifted into the Atchafalaya, an arm of the Mississippi, during an overflow in 1812, amounted to 8,000 cubic feet per minute. The raft thus collected at the mouth of the Red River, is sixty miles long, and in some parts fifteen miles wide." The quantity which descends the Mississippi in a few years might furnish sufficient matter for the largest coal bed known.

The varieties of coal are *brown coal*, or *lignite*,—*bituminous* coal,—*anthracite* coal, and *graphite*, or black lead: this consists of carbon and iron,—and, according to Dr. Hitchcock, "appears to be anthracite which has undergone a still further mineralization." All these varieties of coal occur in seams or beds, interstratified by sandstone and shales: brown coal is found mostly in the tertiary, bituminous in the secondary series, and also with new red sandstone and clay.

Anthracite is found in graywacke, mica slate, limestone, gneiss, plastic clay, and almost all stratified rocks.

Fig. 7. Coal Basin.



[Fig. 7 is a sketch of the great coal basin of South Wales, in Great Britain,—which contains seventy-three beds of coal, whose united thickness is ninety-three feet.]—*Hitchcock.*

PART III.

BOTANY.

CHAPTER I.

Botany is that branch of natural science which investigates the nature and character of, and includes all knowledge in relation to the vegetable kingdom. It treats of the structure, habits, locality, uses, classification and nomenclature of every species of plant known on the globe.

Botany is divided, for the sake of convenience and method, into Physiological and Systematic: *Physiological Botany* resolves itself into *Anatomy*, *Morphology* and *Vegetable Physiology*.

Anatomy treats of the organic structure and relations of all the various parts of plants.

Morphology treats of their form, symmetry, and arrangement.

Vegetable physiology treats of all the phenomena of the vital functions, as absorption, exhalation, digestion, respiration, circulation, germination, &c.

Systematic botany is divided into *botanical classification*, *special descriptive botany*, *glossology*, and *geographical botany*.

Classification treats of the proper grouping and arrangement of plants according to their natural affinities and characters.

Special descriptive botany consists in applying correctly the generic and specific botanical names to parts.

Glossology consists in the explanation and application of names to all the various organs of plants.

Geographical botany treats of the climate, country, zone and locality to which the various species belong.

Finally, botany comprehends, in its most extended sense, a knowledge of the relations of the vegetable kingdom to other departments of natural objects, and the development of the limitless resources of this part of the CREATOR's vast plan for the sustenance and happiness of his creatures.

PRIMARY DIVISIONS OF PLANTS.

The vegetable kingdom is divided into two great natural families, viz: PHENOGAMIA, or that division which includes all *flowering plants*, and CRYPTOGAMIA, or that which includes all *flowerless plants*.

These two divisions are further distinguished by the difference in their elementary structure. The phenogamous, or flowering plants, abound with the *woody* and *vascular* tissues; while the cryptogamous, or flowerless plants, consist almost entirely of the *cellular* tissue. The phenogamia produce seeds having the *cotyledon* and *embryo*,—while the cryptogamia produce minute organs called *spores*, having no such distinction of organs. The phenogamia are therefore called *cotyledonous*, and the cryptogamia, *acotyledonous*. In the former, also, we find a system of compound organs, regularly and successively developed, in the order of root, stem, leaf, flower and seed,—while the latter appear to be "simple expansions of cellular tissue, without order, symmetry or proportion."

CLASSIFICATION OF PLANTS.

All natural sciences classify their respective objects under certain fundamental divisions. The first of these divisions is into CLASSES,—the second divides classes into ORDERS,—the third divides orders into GENERA,—the fourth divides genera into SPECIES, and these are again divided into *varieties*.

The number now known on the whole earth, is between 80,000 and 100,000 distinct species of plants. The classification of plants, and all other natural objects, is founded on the resemblance and differences, in some one or more points, of the individuals of each class, order, &c.

A CLASS, in natural history, comprises an assemblage of objects or individuals, having one or more common characteristics. Thus the whale, the hog and the cow all belong to the class *mammalia*,—because they all have red blood, breathe by means of lungs, and nourish their young by means of milk: the whitewood, rose and locust all belong to the division *phenogamia* and class *angeiosperma*,—because they all produce flowers and woody stems, and bear fruit in capsular vessels.

An ORDER is a subdivision of a class, and divides objects into groups, which are distinguished by more minute and peculiar points of resemblance than those on which a class is based, but still possessing all the peculiar characteristics of that class. The lion, tiger, dog and cat, all belong to the class mammalia and order *carnivora*, because they live, in their native state, on flesh: the water-cress, turnip and mustard all belong to the order *crucifera*, because they all produce flowers having four petals, arranged in the form of a cross.

"A GENUS is an assemblage of species with more points of agreement than difference, and more closely resembling each other than they resemble any species of other groups." This is a subdivision of an order. The dog, wolf, lion and cat, all belong to the same order,—but, on account of certain differences, the lion and cat belong to one genus, and the dog and wolf to another: the apple, cherry, rose and almond, all belong to the order *rosacea*, but they belong to different genera, according to some peculiarity in the organs of each.

A SPECIES "embraces all such individuals as may have originated from a common stock: such individuals bear an essential resemblance to each other, as well as to their common parent, in all their parts." This is a subdivision of a genus. The white and red clover both belong to the genus *trifolium;* but they differ in some minor points sufficiently to place them in different species.

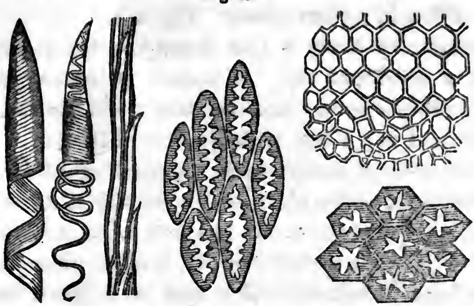
A *variety* is a subdivision of a species, and is the last distinction made in any system of classification: varieties in the vegetable kingdom occur principally in the cultivated species; they depend only upon slight differences, as, for instance, the same apple tree, rose bush, or potato vine, may produce fruit, tubers and flowers of different colors, but still alike in all *essential* characteristics.

We see through the whole vegetable kingdom, a most marked analogy and connection, from the minutest organized microscopic plant, to the largest forest tree: there are also differences so obvious that there can be no doubt of the propriety of arranging them into different groups according to their peculiar characters.

ELEMENTARY ORGANS OF PLANTS.

The most simple and elementary form of a plant is that of the *embryo*, which is produced by, and contained in the seed. This consists of two parts, viz: the *plumula* and *radicle.* The plumula is the part which is afterwards developed into the ascending part of the plant, the stem, branches and leaves. The radicle is that which becomes the root, and descends into the earth in search of food and moisture. The ascending part of the young plant is at first merely a minute growing point, enveloped in delicate rudimental leaves, which constitute a *bud.*

Fig. 1.



[Fig. 1,—Forms of tissue; a, cutting of elder pith, cellular; b, cells from the gritty centre of the pear; c, from the stone of the plum—both strengthened by solid matter; d, woody fibre; e, spiral vessel with a single fibre partly drawn out; f, vessel with a quadruple fibre.—*Wood.*]

The several elementary structures of which the various parts of plants are made up, are called *elementary tissues:* they are five in number, viz: the *cellular, woody, vasiform, vascular,* and *laticiferous.* The *chemical elements* of which these tissues are composed, are enumerated and described in works on chemistry.

Cellular tissue is composed of a series of minute cells attached together, and having a more or less regular form. Fig. 1, a.

Woody tissue consists of minute tubes, tapering to a point at both ends, and adhering by their sides, the end of one tube overlapping that of another so as to form continuous threads. Fig. 1, d.

The *vasiform tissue* consists of tubes, large enough to be seen by the naked eye in some plants,—as, for example, in a transverse section of the oak. In some plants these tubes are jointed, or divided by partitions, and in others they are continuous. It is through these that the sap rises, and they are the largest vessels in the vegetable organization. Fig. 2, a.

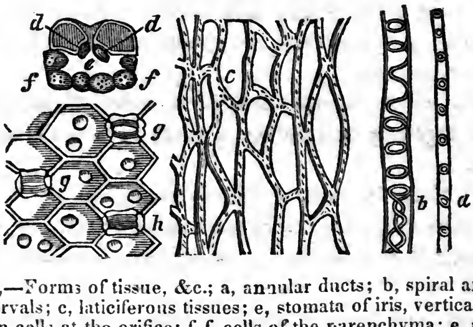
Vascular tissue consists of spiral vessels, resembling somewhat the woody fibre; they contain air, and their internal structure differs in various plants. Fig. 2, b.

The *laticiferous tissue* is that through which is circulated the *latex*, or nutricious sap. It consists of minute, irregular branching tubes opening into each other, and situated mostly in the bark and under side of the leaves. Fig. 2, c.

The *epidermis*, or outside bark, is formed of celluar tissue, and envelopes the entire plant, except the stigma of the flower, and the spongioles of the roots. In plants whose bark is rough and ragged, as in the walnut and oak, it is not distinguishable.

The delicate membrane which may be stripped from the iris, or house leek, is the epidermis; this covering of plants is perforated by minute orifices or mouths, which open and close by the presence or absence of light. The epidermis and leaves have several appendages, as *glands, hairs, prickles, thorns*, *receptacles* and *stings*, which it is not necessary to describe in this treatise.

Fig. 2.



[Fig. 2,—Forms of tissue, &c.; a, annular ducts; b, spiral and annular at intervals; c, laticiferous tissues; e, stomata of iris, vertical section; d, d, green cells at the orifice; f, f, cells of the parenchyma; e, air chamber; g, g, epidermis and stomata of yucca; h. stomata closed; the dots represent small luminous bodies in the cells.—*Wood*.]

CHAPTER II.

ORGANS AND STRUCTURE OF THE FLOWER.

THE essential organs of a flower are three, viz: the *stamens*, the *pistils*, and the *receptacle*. These are all the parts necessary to the perfection of the seed,—they therefore constitute a perfect flower: to these, however, is added in most flowers, the *perianth*, consisting of the *calyx* and *corrolla*.

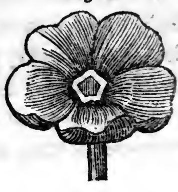
The STAMENS are slender, thread-like organs within the "flower" or perianth, around the pistils: their most common number is five: but this varies from one to a hundred. Their office is said to be the fertilization of the seed.

The PISTILS are usually slender, larger than the stamens, and occupy the centre of the flower: "they are destined to bear the seed." They are sometimes numerous, but in many cases there is only a single one.

The RECEPTACLE is placed at the end of the flower stalk, and constitutes the basis upon which the organs of fructification are usually placed, in such manner as to encircle it.

Fig. 3.

Fig. e.



The CORROLLA is the interior part of the perianth, consisting of one or more circles of colored leaves of various hues and delicate texture, situated upon the receptacle: these leaves are called *petals*, (Fig. 4, a, a,)—and they may be united at the edges, constituting a bell-form flower, (Fig.3,) or they may be separate, constituting a wheel-form flower. Fig. e.

Fig. 4.

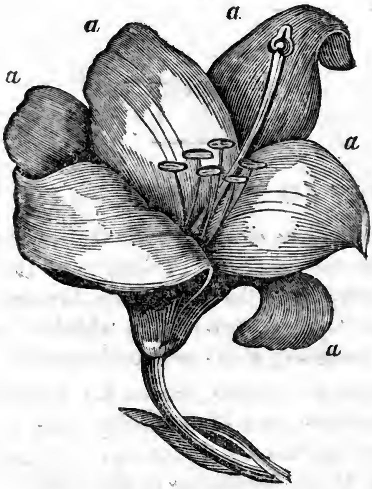
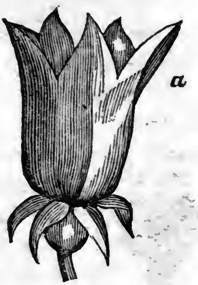


Fig. 5.

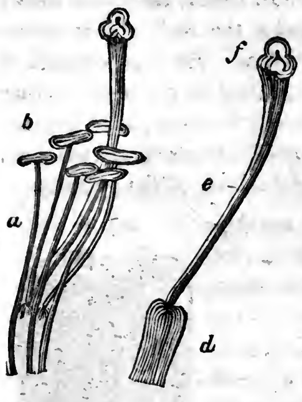


The CALYX is the external part of the perianth, consisting of a circle of leaves, the same in number as those of the corrolla, in some cases distinct, and in others united: they are usually green: these leaves are called sepals. Fig. 5, a.

We see now, that a complete flower is made up of four regular sets of organs, viz: the *stamens, pistils, receptacle* and *perianth:* these organs are arranged in concentric *whorls*, or rings: some of them may be absent, or suppressed, some superfluous ones may be developed and some degenerated into those of a different set, as petals into stamens, flowers into leafy branches, &c.

The *stamen* consists of three distinct parts, viz: the *filament*, (Fig. 6, a,) the *anther*, (Fig. 6, b) and the *pollen*. The filament is the thread-like part which supports the anther at its summit: the pollen is a fine yellow dust of various forms contained within the cells of the anther, until discharged through its pores into the air.

Fig. 6.



The *pistil* consists also of three parts, viz: the *ovary*, the *style*, and the *stigma*.

The *ovary* is the base of the pistil which contains the young seeds, and which ultimately becomes the fruit. Fig. 6, d.

The *style* is a prolonged column arising from the ovary, and supporting the stigma at its top. Fig. 6, e.

The *stigma* is the upper extremity of the style, usually of a globular form: it may be either simple or compound, according to the structure of the ovary and style. Fig 6, f.

The *ovules* are minute globular bodies in the cells of the ovary, which become the seeds of the matured fruit.

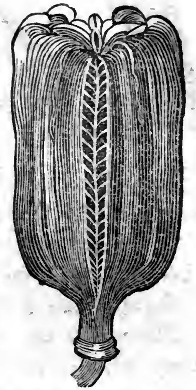
The *placenta* is a fleshy ridge within the cells of the ovary, from which the ovules are developed, and to which they are attached.

There are several other secondary and minute parts, belonging to the flower, which it is not necessary or practicable to describe here, as it would only burthen the memory with technical terms which would convey but little useful knowledge.

THE FRUIT.

The ultimate object of the whole vegetable organization appears to be the production of fruit; which is the agent through which the reproduction of the species is accomplished. After the seed is perfected in annual plants, they soon wither and die: the flower always precedes the fruit, and is necessary to its development and perfection. The fruit consists of two parts, viz: the *pericarp* and the *seed*, or the seed-covering and the seed: the pericarp is wanting in some plants, but the seed is essential in all. In the coniferous plants, as the pine, spruce, &c., the seed is naked and destitute of the pericarp.

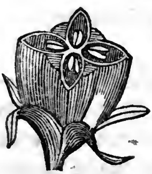
Fig. 7.



The PERICARP is the part which envelops the seed, whatever be its substance or structure. Fig. 7. In the peach and plum, this is a fleshy, pulpy substance,—in the oak and walnut, a dense hard shell: (fig. 8.) thus the structure and composition of the pericarp varies in different plants, from a soft watery pulp to a dense shell. The process of the ripening of fruit consists of certain chemical changes produced by the action of light, heat and air, and perhaps other agents. Pericarps have received specific names, according to their form and structure: that of the pea and bean is called a pod,—that of the walnut and butternut is called a nut,—that of the apple and pear, a pome,—that of the currant and whortleberry, a berry, &c. Fig. 9.

Fig. 8.

Fig. 9.



This figure represents the pericarp, or seed capsule of the œnothera.

THE SEED.

The seed contains the rudiments of a new plant, and is the final product of all the complicated and beautiful processes of vegetation. The essential parts of the seed are, the *integuments*, the *albumen* and the *embryo.*

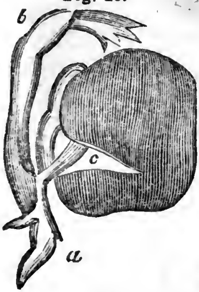
The *integuments* are composed of several distinct layers, which constitute the immediate coverings of the other parts.

The *albumen* lies next to the integuments, constituting the principal bulk of some seeds; it is a whitish substance, composed mainly of starch, which, by the chemical changes which it undergoes during the process of germination, serves to nourish the embryo plant.

The *embryo* comprises all the rudiments of the new plant: it consists of three parts, viz: the *radicle*, the *plumule*, and the *cotyledon.*

The *radicle* is the part which forms the root,—the *plumule* forms the ascending portion of the plant,—the *cotyledon* is the bulky part of seeds, and forms the first leaves of young plants, which in the garden bean, cucumber, &c., are thick, fleshy and oval, when they first rise above the surface of the ground: these support the plant and perform the function of leaves until the proper leaves are formed.

Fig. 10.



[This figure shows an embryo with its plumule and radicle developed from the cotyledon: a, radicle; b, plumule; c, cotyledon.]

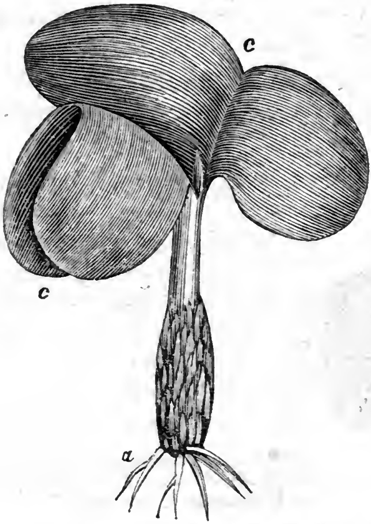
GERMINATION OF SEEDS.

Germination consists of the first chemical changes and vital action, which take place when a new plant is about to be produced.

"When the seed is planted in a moist soil, at a moderate temperature, the integuments gradually absorb water, soften and expand. The water is decomposed, its oxygen combines with the carbon of the starch which has been stored up in the tissues. Thus, losing a part of its carbon, the starch is converted into sugar for the nourishment of the embryo, which now begins to dilate and develop its parts. Soon the integuments burst, the radicle descends, seeking the damp and dark bosom of the earth, and the plumule rises with expanding leaves, to the air and light. The conditions requisite for the germination of the seed are, heat, moisture, oxygen, air and darkness."

[Wood.

Fig. A.



[Fig. A. This cut represents a young dicotyledonous plant, with its radicle, a, developed; its cotyledons, c, c, appear in the form of large succulent leaves; the plumule is just appearing as a minute point between the cotyledons.]

THE ROOT.

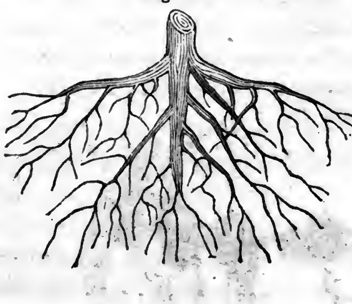
The *root* constitutes the basis of the plant: it serves two purposes in the vegetable economy,—first to fix the plant mechanically in the soil and retain it in its position,—secondly to absorb from the soil those inorganic elements which are necessary for its food. The general direction of the root is downwards; but the roots of various plants grow at all angles from the horizontal to the perpendicular: the principal perpendicular axis is called the *tap root.* The number and extent of the roots must correspond with those of the stalk and leaves of the plants, in order to supply their demand of food from the soil.

Roots do not usually extend to great depths, but keep within the limit of that portion of soil which supplies their proper nutriment. Roots are distinguished from stems and branches by the absence of stomata, buds and pith,—and by the presence of absorbing fibres.

The *stock,* or main body of the root, sends off the *fibrils,* or minute, slender branches of the root,—the delicate, tender extremities of the fibrils are called *spongioles:* these are the growing points, and the organs which absorb from the soil the earthy part of the food of all plants. If some trees, as the willow or currant, be inverted in the soil, the branches are changed to roots, while the roots put forth leaves in the air, and the plant grows.

Roots are of several different forms, which have received specific names for the sake of convenience.

Fig. 11.

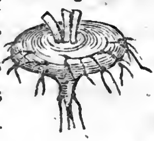


Ramose, or *branching* roots, are those which send off many ramifications in various directions, like the branches of a tree: such are the roots of the oak and elm. Fig. 11.

Fig. 12.

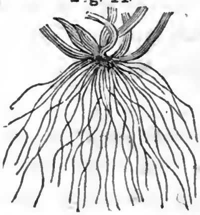
Fusiform, or *spindle shaped* roots, consist of a fleshy stock, tapering downwards to its extremity, sending off fibrils, which are its true roots: such are the raddish, carrot and parsnep. Fig. 12.

Fig. 13.



The *napiform* root is a variety of the fusiform, in which the neck or upper part swells out, so that its diameter equals or exceeds its length. The turnip and turnip-raddish are examples. Fig. 13.

Fig. 14.

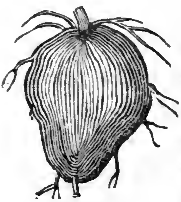


Fibrous roots are made up of numerous small thread-like roots, attached directly to the stalk, without any neck or main root: such are the roots of most grasses. Fig. 14.

Fasciculated roots differ from the fibrous in having some of their fibres thickened and fleshy, as in the dahlia and peony.

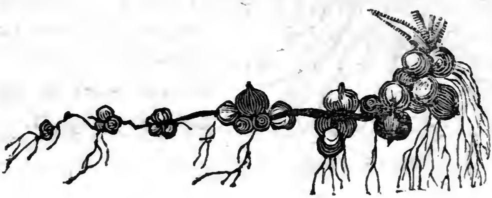
Tuberous roots consist of fleshy, roundish knobs or tumors, at or near the extremity of the stalk, as in the orchis: "the potato was formerly classed among tubers,—but as it uniformly bears buds, it is classed among stems." Fig 15.

Fig 15.



Granulated roots consist of many small rounded bulbs connected together by fibres, as in the common wood sorrel. Fig. 16.

Fig 16.



Besides these varieties of roots, there are several others which are peculiar, and distinguished by not being necessarily fixed in the soil.

Aerial roots are those which grow from some part of the plant above the surface of the soil in the open air. Some creeping plants, as the ground ivy, send forth these roots from their joints. The screw-pine also sends off roots which are several feet in length before they reach the ground. Such roots are often seen in the common maize.

Floating roots belong to plants which float upon the surface of water. The water-starwort is said to float upon the surface until flowering, when it sinks and takes root in the mud till its seeds ripen.

The *epiphytes*, or plants fixed upon the branches of other species, derive their nourishment mostly from the air: such are some species of moss.

Parasites are those plants which grow upon other plants; and some of whose roots are said to penetrate their tissues and subsist upon their juices; while the roots of others are aerial, and derive their food from the air: such are the mistletoe and dodder.

Roots are divided again into three varieties, viz: annual, biennial and perennial, according to their duration.

Annual roots are those which live only one year, and must be raised from the seed, sown every spring,—as beans, peas and cucumbers.

Biennial roots are those which live two years and do not blossom the first season,—but they produce flowers, fruit and seeds the second year, and then die: such are the beet, cabbage and carrot.

Perennial roots live several years,—some of them, as forest trees, live to a very great age: the grasses, dandelion and asparagus are other examples.

STRUCTURE AND FUNCTIONS OF THE ROOT.

The internal structure of the root and stem are similar: the fibrils are composed of vascular tissue, inclosed in a cellular epidermis, which, however, does not extend to the ends of the fibrils;—these ends are naked and spongy,—hence they are called spongioles, and have the power of absorbing large quantities of water.

The growth of the root takes place by layers upon its surface and the addition of matter at the extremities. The fact is considered established, [Johnston,] that the spongioles absorb gaseous as well as aqueous matters, when in contact with them. The root absorbs only from its spongioles;—from these it is carried by the vessels of the fibrils to those of the main roots, and thence into the stem and to all parts of the plant. 1. Both organic and inorganic substances, in a state of solution in water, enter the circulation of plants. 2. The roots have the power of selecting such substances as are necessary for their food, and of rejecting those that are injurious to their healthy growth. 3. Roots possess the power of excreting certain matters which are in excess, or are unnecessary or injurious to them. 4. Roots have the power of modifying the fluids as they pass through them.—[Johnston.]

THE STALK OR STEM.

The part of a plant which rises above the surface of the soil, which constitutes the principal axis, and is intermediate between the roots and branches, is called the *stem*. The direction of the stem is generally vertical, but in some plants it is oblique or horizontal. Stems, like roots, may be *annual*, *biennial* or *perennial*. Plants are divided into *herbs*, *shrubs*, and *trees*, according to the size and duration of the stem.

Herbs are plants with annual roots and annual stems, which do not become woody: such are the grasses, mints, most flowers, &c.

Shrubs have perennial, woody stems and roots, divided into numerous branches near the ground, and do not attain the size of trees: such are the alder, whortleberry, lilac and hawthorn.

Trees have perennial, woody stems and roots,—do not branch off near the ground, and attain a great size: examples, elm, oak and pine. The distinguishing property of the stem is the production and development of *buds*.

Buds are of two kinds, viz: the *leaf-bud* and the *flower-bud*.

The leaf-bud consists of delicate layers of cellular tissue, or embryo leaves, covered by hardened crusty scales.

The flower-bud consists of the rudiments of the new flower.

There are several subordinate organs, which are little more than appendages to the stem, and which it is unnecessary to describe.

STRUCTURE AND FUNCTIONS OF THE STEM.

Plants are divided into *exogenous* and *endogenous*.

The *exogenous* are those which grow by accumulation, or layers of matter from the outside. This class includes nearly all forest trees and most shrubs and herbaceous plants of temperate climates.

The *endogenous* plants are those which grow from the inside, or by accretion of matter within that already developed. Most of the bulbous plants of temperate regions, all the grasses, and the palms, cane, &c., of tropical countries, are endogenous.

The *exogenous* stem consists of bark, wood and pith.

The *pith* is a light spongy substance, at the centre of the stem: it is composed of cellular tissue, and seems to exercise its peculiar functions only during the earlier growth of plants.

[Wood.

The *wood* is composed of cylindrical or concentric layers, intersected by medullary rays, which are those thin dense plates of wood dividing the "grains," and are large and easily seen in a piece of beech or oak wood which has been split. The pith, together with the first layer which incloses it, are the

Fig. 17.

1

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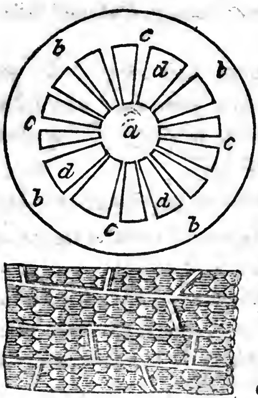


product of the first year's growth; one new layer is formed every succeeding year,—so that the number of rings or "grains" at the base of the stem indicate correctly the age of the tree. Each layer is composed of woody fibres, vasiform tissue and ducts. Fig. 17.

[Fig. 17. 1, represents an erogenous stem of one year's growth; a, pith; b, bark; c, medullary rays; d, woody bundles of fibre; 2, laticiferous vessels of the bark.]

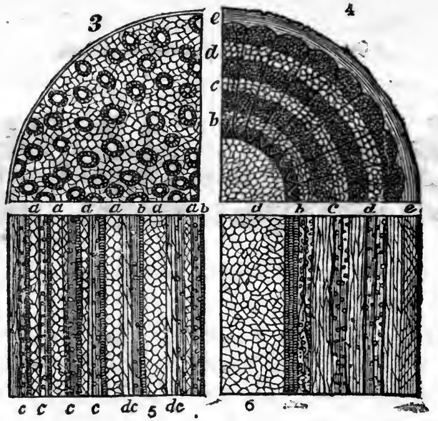
The outside, lighter colored layers constitute the *alburnum* or "sap wood:" the brownish layers inside are harder than the sap wood, and are hence called the *duramen.*

The bark forms the external covering or integuments of the stem and root. The bark consists of three distinct layers: the outside covering is called the *epidermis,*—this layer is sometimes covered with a coating of gummy, oily or resinous matter. The middle layer is the *cellular integument;* and the inner coat the *liber.* The two outer layers are of cellular structure, while the inner one is both cellular and woody.

The *sap* is carried by the vessels through the alburnum to the leaves, with the vessels of which they communicate: while in the leaves, the sap undergoes some changes, (not well understood,) by means of the air and light, by which it is converted into a fluid called *latex.* From the vessels of the under side of the leaf, it descends by the vessels of the inner bark; part of it is carried inwards by the pores of the medullary rays, and diffused through the stem, while the remainder descends to the roots, and is distributed through them. Sap is milky, gummy, saccharine bitter, &c., in various plants.

At the end of spring a portion of the descending sap, which is now transformed into a viscid glutinous matter called *cambium*, is deposited between the liber and the wood, becomes organized into cells, and forms a new layer upon each. Soon afterwards, the new layers are pervaded by woody tubes and fibres, which commence at the leaves and grow downwards. "The number of layers in the bark and wood will always be equal." (Wood.) The outer bark of young twigs seems to perform the same function as the leaves: in the cactus, stapelia, and other plants which produce no leaves, the bark must perform the same office as the leaves do in plants which produce them. (Johnston.)

Fig. 18.



[Fig. 18. 3, horizontal section of an endogenous stem, exhibiting the bundles of woody fibre, spiral vessels and ducts, irregularly disposed in the cellular tissue: 5, a, a, cellular tissue; b, spiral vessels on inner side of dotted ducts, c, c; d, woody fibre on the exterior side: 4, stem of three year's growth; a, pith; e, bark; b, c, d, successive annual layers: 6 a, pith; b, spiral vessels of the medullary sheath; c, dotted ducts; d, woody fibre; e, bark.]

The *endogenous* stem exhibits no distinction of bark, wood and pith,—and no concentric annual layers or grains. It is composed of cellular tissue, woody fibres, spiral vessels and ducts, the same as that of exogens. The cellular tissue exists equally in all parts of the plant; the rest are in bundles, imbedded in the stem: "each bundle consists of one or more ducts, with spiral vessels adjoining their *inner* side next to the centre of the stem, and woody fibres on the outside, as in the exogen.

"A new set of these bundles is formed annually, or oftener, proceeding from the leaves, and passing downwards in the *central* parts of the stem, where the cellular tissue is most abundant and soft. After descending awhile in this manner, they turn outwards and interlace themselves with those which were previously formed."

Cryptogamous or Flowerless Plants.

CHAPTER III.

STRUCTURE AND FUNCTIONS OF THE LEAF.

The *leaf* is an extension of the two outer layers of the bark expanded into a broad thin net work: leaves constitute the verdure of nearly all plants; their color is almost universally green, which color they derive from a substance called *chlorophylle*, deposited just beneath the cuticle. Towards the end of autumn, after the verdure of plants has matured, their color is changed to various hues, as yellow, orange, red, &c., by the action of oxygen on their elements.

Deciduous leaves are those which fade and fall off at the end of autumn, annually.

Evergreens are those which remain green throughout the year.

Leaves are arranged in various ways upon the stem and branches of plants: in some, as in the potato, they are *scattered* along the stem irregularly: in others, as the pea, they are *alternate*, or one above another on opposite sides of the stem: when two are against each other at the same joint or node, they are called *opposite:* when more than two are arranged in a circle at the same node, as in the meadow lily, they are *verticillate:* in the pepper and some others, they are arranged *spirally* around the stem.

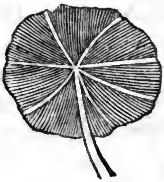
The prolongation of the leaf-stalk, through the middle of the leaf, is called the *midrib:* the smaller divisions, or ribs, which radiate or go off from this, are called *nerves.*

The hair-like lines sent off from the midrib and nerves are called *veins*. This distinction is arbitrary, as there is no difference in the structure or function. The various distributions of the veins have received distinctive names, and these are all included under the generic term *venation*.

FORMS OF LEAVES.

The *forms* of leaves have also subjected them to an arrangement under specific heads. The forms of leaves are said by De Candolle to depend upon the length of the midrib and the relative length of the veins.

Fig. 19.



Orbicular leaves are roundish, as in the pyrola rotundifolia, or round leaf wintergreen, and nasturtion. Fig. 19.

Fig. 20.

Elliptical leaves, as their name implies, are elliptical or oval in form, as in the whortleberry and wintergreen. Fig. 20.

Lanceoate leaves are long and tapering at the point like the blade of a lancet, as in the willow and peach. Fig. 21, *a*.

Fig. 21.

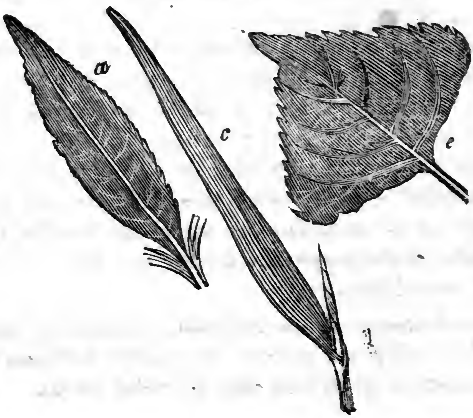


Fig. 22.

Fig. 23.

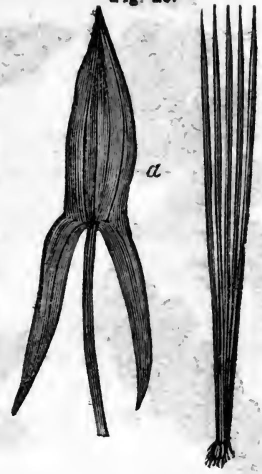
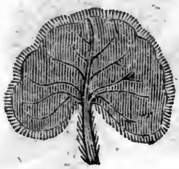


Fig. 24.



Cordate leaves are heart-shaped, as in the lilac and aster cordifolium. Fig. 22.

Sagittate leaves have the form of an arrow-head, as in the sagittaria. Fig. 23, *a*.

Reniform leaves are kidney-shaped, as in the wild ginger and ground ivy. Fig 24.

Linear leaves are narrow, long and straight, as in the grasses and grains. Fig. 21, *c*.

Deltoid leaves are in the form of the Greek letter delta, or nearly triangular, as in the Lombardy poplar. Fig. 21, *e*.

Acerose leaves are long, narrow and needle-shaped, and clustered together, as in the pine. Fig. 23, *b*.

Pinnatified, or feather-cleft leaves, have deep clefts between all their veins, separating the leaf into parallel segments, as in the lepidium. Fig 25, *d*.

Fig. 25.

Fig. 26.

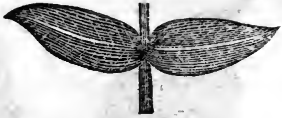


Fig. 27.

Lyrate leaves have several deep rounded notches between their veins, as in the water-cress. Fig. 25, *c*.

Connate leaves have the bases of opposite leaves united so as to appear like one entire leaf, as in the boneset and saponaria.. Fig. 26.

Digittate leaves have narrow, deep clefts between the veins, with long segments radiating from the end of the leaf-stalk, as in the common hemp. Fig. 27.

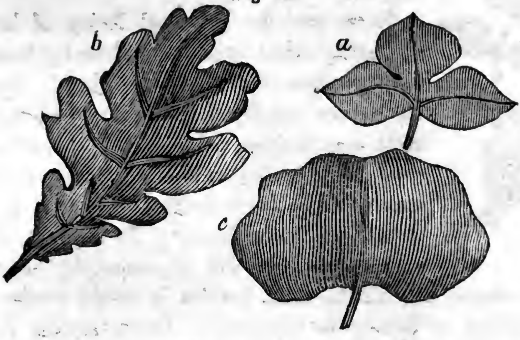
Fig 28.

Stellate leaves are arranged around the stem in such a manner as to form a star, as in the red lily. Fig. 28.

Lobed leaves are deeply indented or cleft at their margins, so as to divide them into lobes, as in the liverwort. Fig. 29, *a*.

Sinuate leaves have their margins divided by deep roundish clefts, as in the white oak. Fig. 29, *b*.

Fig. 29.



Emarginate leaves are irregular, having but slight indentations in the margin. Fig. 29, *c*.

Tubulate leaves have the sides or margins united so as to form a cup, as in the side-saddle and pitcher plant. Fig. 30.

Fig 30.

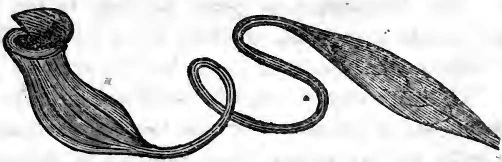
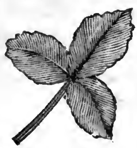


Fig 31.

Compound leaves consist of several small leaves on separate leaf-stalks, and arranged along the opposite sides of the same stem, as in the hedysarum. Fig. 31.

Fig. 32.



Ternate leaves arise in threes from the same leaf-stalk. Fig. 32.

Biternate is a second division by threes.

Fig. 33.

Leaves are opposite when placed at equal distances in pairs on opposite sides of the stem. Fig. 33.

These are the principal forms of leaves; still, many other names are given by botanists to the various modifications of these. Specific terms are employed also in describing the stem, margin, base, point and surfaces of leaves.

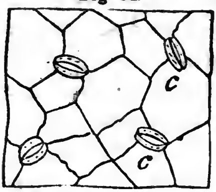
There are also various appendages to the leaves, which have distinctive names, in systematic works on botany. To describe all the minor points in the organography of plants would exceed our limits,—and, besides, it would render this brief outline of botany too complex to be interesting to the general reader.

MINUTE STRUCTURE OF THE LEAF.

The frame work of the leaf is an extension and expansion of the medullary sheath, which is composed of woody fibre and vessels. The integument, or outer covering of the leaf, is the same as that of the bark, of which it is a continuation.

The cellular tissue peculiar to the leaf is called its *parenchyma.* This parenchyma exists in two layers of cells, which differ somewhat in structure. Within the cells, and adhering to their walls, are the minute green particles of *chlorophylle,* which give color to the leaf: the empty spaces between the cells communicate with the external air by means of *stomata,* or mouths, which, in most plants, are found only on the lower surface.

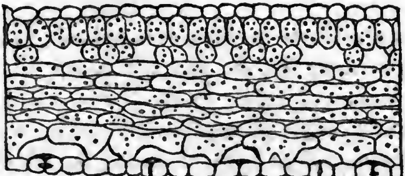
Fig. 34.



[Fig. 34. Magnified section of the epidermis of the lily, showing the stomata, c, c.

In all those plants whose leaves are vertical, as the iris, they are on both sides equally: in the water lily, they exist only in the upper surface, the lower surface being in contact with the water. The veins which carry the *latex*, or nutricious fluid of the leaf, "having reached the edge of the leaf, double back upon themselves," spread through the lower surface, and are again collected, and returned through the leaf-stalk into the bark.

Fig. 35.



[Fig. 35 shows a magnified section of the leaf of the lily: the upper surface, a, consists of flattened cells of the epidermis, arranged in a single layer; beneath this, b, is the more compact part of the parenchyma, consisting of a layer of oblong cells placed in such a position that their longer axis is perpendicular to the leaf's surface. Next below is the parenchyma of the lower surface, c, composed of oblong cells arranged longitudinally, and so loosely compacted as to leave larger spaces between. Lastly, d, is the epidermis of the lower surface, with stomata, e, e, opening into air chambers, f.]

FUNCTIONS OF THE LEAF.

The functions of the leaf are, *exhalation, absorption, respiration* and *digestion.* The ultimate end of these functions is to produce the necessary changes on the crude sap brought up from the roots, and to convert it into the latex, which is the proper nutrition of the growing plant: this fluid is to the plant what the arterial blood is to the animal system.

Exhalation in plants is the throwing off of the excess of water in the sap, so as to leave it in a more concentrated form, and consequently better adapted to nutrition: exhalation takes place through the stomata, and is different from mere evaporation, which depends upon the state of temperature and air. Exhalation is supposed to cease during darkness.

Absorption is performed mainly by the roots, in nearly all plants: when, however, these are defective or wanting, the leaf assumes the vicarious office of absorption. The invigorating effect of a shower of rain on the leaves of parched and wilted plants, is seen long before the water could have reached the roots and have been carried up to the leaves: this effect must be produced, therefore, by the absorption of moisture by the leaf. This action takes place mostly from the lower surface of the leaf.

Respiration in plants consists, as in animals, in the absorption of oxygen from the air, and the giving off of carbonic acid. It is performed mainly by the leaves, but is performed to some extent by other parts also: it continues without intermission by day as well as by night, during the life of the plant. Respiration is most active during the processes of germination and flowering: a constant supply of oxygen, and the daily presence of light, are indispensable to the growth and vitality of the plant.

Digestion comprises all those changes which the mineral, aqueous and gaseous matters undergo after entering the plant, until they are assimilated and become a part of the organism. "It consists in the decomposition of carbonic acid by the green tissues of the leaves, under the stimulus of the light, the fixation of the solid carbon, and the evolution of pure oxygen."

[Wood.

INFLORESCENCE.

Inflorescence is the term used to indicate the peculiar arrangement of flowers upon the stem and branches of plants; also their successive development in different parts of the same plant. Flowers are said to be terminal and axillary, in regard to their position on the stem.

Terminal flowers are placed at the end or summit of the branch or flower stalk.

Axillary flowers are placed in the angle formed by the branch or leaf-stalk, and the primary central stem, or larger lateral branches.

The *peduncle* is the flower-stalk, or that part of the stem which is attached to and supports the flowers: it may be simple or branching, and it may be entirely absent.

Fig 36

[Fig. 36 shows a papilionaceous flower with its peduncles.]

A *scape* is a flower-stalk, or peduncle, which springs immediately from the root, in those plants which are called stemless, as the sarracenia, hyacynthus, &c.

A *rachis* is the main axis, or stem, of a compound peduncle, along which are arranged the flowers, as in the currant, grape, grasses, plantain, &c.

A flower is said to be *solitary*, when a single terminal or axillary flower is developed, as in the erythronium and convolvulus. The successive evolution of flowers is distinguished into two varieties, viz: the centripetal and centrifugal.

In *centripetal inflorescence*, the blooming of the flower commences at the circumference and proceeds towards the centre, as in the mustard, carrot, &c.

In *centrifugal inflorescence*, the blossoming commences at the terminal or central flower, and advances laterally to the circumference, as in the elder, pink and sweet-william. These two modes of inflorescence are sometimes combined in the same plant.—[Gray.]

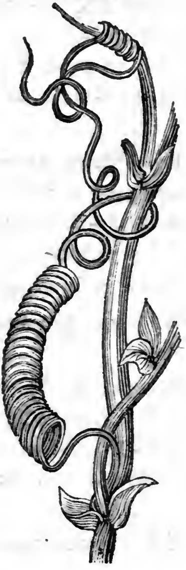
There are several varieties of centripetal inflorescence, which are designated by specific terms; as the spike, raceme, ament, spadix, corymb, umbel, head, panicle and thyrse.

Of centrifugal inflorescence, there are also several varieties, as the cyme, fascicle, whorl, or verticil, &c.

Fig 37.

[Fig. 37 represents a head of oats showing an example of a panicled flower.]

Tendrils.



CHAPTER IV.

GENERAL REMARKS.

The *dissemination* of seeds is a subject not unworthy of allusion. It is known to botanists, that nearly all plants have particular localities to which they are indigenous. But, by various means, they have become more or less distributed over different and distant parts of the earth. Some seeds, as those of the thistle and dandelion, are furnished with a little plume or wing, by means of which they are wafted by winds to great distances, and thus sown in a soil and locality where the species was never before known. Some seeds are furnished with hooks or burs, by means of which they attach themselves to the clothing of men and animals: seeds are also eaten by animals and birds, carried to great distances, voided undigested and without injury to their vitality, germinate wherever they are deposited.

Many seeds are so protected by a thick dense pericarp, that they make long voyages, being carried along by the current of streams, or the ebbing and flowing of tides, until they reach a distant country, and perhaps even another continent, and there propagate and establish their species. They are carried also by ships and other conveyances engaged in commercial transportations, as well by accident as by design for the purpose of cultivation. Many seeds retain their vitality after boiling, digestion in alcohol, and being buried in the earth for centuries. Dr. Lindley mentions a remarkable instance of the *longevity* of raspberry seeds, which, as proven by circumstances, must have been 1,600 years old, and were found thirty feet below the surface of the earth. Oily seeds are more liable to putrify and lose their vitality than others.

The *blooming of flowers* was thought, during the dark and middle ages, when the human mind was blinded by the grossest superstition, to be emblematical of something connected with religion: thus when the time of the blossoming of a flower fell on the birthday of a saint, or on the day of a martyrdom, that flower was consecrated or dedicated to such saint or martyr.

Plants exhibit many phenomena which seem to be connected with atmospheric conditions and changes: thus it is said a storm may be predicted by the folding or opening of certain flowers; also that a clear sky, thunder, wind, &c, may be foretold by the various other phenomena observed to take place in the different organs of plants. Some plants are capable of enduring a high degree of heat: those of the tropics sustain a temperature which would be intolerable to animals for a great length of time: others are found immersed in the waters of boiling springs, and in a state of thrifty vegetation.

Every country exhibits a flora, or botanical character, peculiar to itself. The influence of light and heat on the growth of plants is seen to be powerful and important. In the polar regions, where almost perpetual winter reigns, the vegetation is rigid, scanty and stinted: the centre of the frigid zone, in fact, is totally destitute of vegetable life. After passing the arctic circle, we find a few species of mosses, lichens and ferns, and a few shrubs. The only country in this zone where the grains can be successfully cultivated, is Lapland. The temperate zone produces most species of useful nutrient plants, such as the grains, berries, fruits and grasses, as well as valuable timber trees. The torrid zone produces every variety of vegetation from the equator to the poles: this variety depends upon the altitude at which they are found; the low land produces the most luscious fruits and stately trees, with a vast variety of flowers and spices.

As vegetation ascends the mountain heights, even under the equator, it assimilates, according as the climate becomes less congenial, to that of the colder regions, in the same way as when receding from the equator towards the poles. Plants, like animals, are liable to various diseases: no inorganic body can be said to suffer from disease,—although they are subject to decomposition and disintegration, they are not capable of diseased action, because destitute of vitality, which is indispensable to such a process. Plants may become diseased from a deficiency or excess of food, air, light, water, heat,—or from cold, noxious vapors, external injuries, insects, parasites and hereditary organic or functional debility. They are also liable to diseases peculiar to old age and excessive action, in the same manner as animals. Thus they suffer from *anemia,** or want of fluids, like aged persons: they sometimes labor under dropsy, from deficiency of light,—and from other causes they suffer and die from *dry mortification.**

Lastly, plants are liable to disease and death from poisoning and contagion. The economical uses of plants are well known, and require only a passing notice: forest trees, and some parts of other plants, are indispensable in the arts: cereals, fruits and roots, are used as food for both man and beast: the grasses, lichens, mosses and herbs serve as food for animals: various plants, and the substances derived from them, are also used as medicines. Plants designed for medicinal purposes should be collected at a time when the whole vitality and forces are not engaged in the growth of the plant and maturity of the flower and seed: herbs should be gathered soon after flowering, or when the seed is nearly ripened: roots, if annual, should be

* Terms proposed by the author.

gathered after the stem and foliage are withered in autumn, or before the old root begins to decay in the spring: barks possess more strength if taken after the descent of the sap has ceased, and the cambium has become hardened into wood and bark.

Some remarks on the collection and preparation of plants for herbariums, and upon botanical analysis, classification and nomenclature, might be made; but they would be of little service, as they would anticipate a step in the science which lies beyond the limits of this treatise.

PART IV.

METEOROLOGY.

CHAPTER I.

METEOROLOGY is the science which treats of all the various phenomena which take place in the atmosphere. "Under the term meteorology, it is now usual to include, not merely the accidental phenomena to which the name of meteor is applied, but every terrestrial as well as atmospherical phenomenon, whether accidental or permanent, depending on the action of heat, light, electricity, and magnetism. In this extended signification, meteorology comprehends climatology and the greater part of physical geography; and its object is to determine the diversified and incessantly changing influences of the four great agents of nature now named, on land, in the sea, and in the atmosphere."—[Brande.]

A *meteor* is any phenomenon of a transitory nature, which appears in the atmosphere. The various conditions and changes which take place in the air incessantly, with respect to heat, cold, moisture, dryness, &c., are called *weather*. Observations have been made in all ages of the world upon these phenomena, in order to explain their causes and foretell the changes of weather. But there are so many conditions to be considered, and so many influences which probably can never be understood, that there is little certainty in all the theories and weather tables which have been formed. Although many of the meteorological phenomena are somewhat well understood in their individual nature, still, when they are combined, their operation is exceedingly complex, and the number of their changes almost infinite.

Records of past changes of weather have long been kept, but it has been found by observation and comparison of the results of different seasons and years, that few data are obtained, on which to ground any prognostications of the future. Some individuals have, by long and close observation, attained some apparent accuracy of judgment in relation to the phases of the weather; but their conclusions were not of a nature to be systemized and transmitted to posterity; so that, if any real attainment has been made in this way, it has always been lost with the observer.

"The registers which are kept in different observatories, prove, contrary to popular belief, that the changes of weather are in no way whatever dependent on the phases of the moon." Although the ever varying and endless changes of weather are all the necessary results of fixed laws, yet it is doubtful whether these laws will ever be sufficiently understood to enable us to reduce our knowledge respecting them to demonstrative ccertainty.

CLIMATE.

Climate, in its most extended signification, embraces all the modifications of atmospheric temperature and conditions, and the principal causes on which they are dependent: besides temperature, it includes humidity, dryness, winds, barometrical conditions, purity of air, &c. The principal causes which tend to modify climate are, latitude, altitude, direction in which the sun's rays fall upon the earth, configuration and aspect of the land, its proximity and relation to the sea, direction of the wind, density of the atmosphere, number of rays of the sun which are absorbed, amount of vegetation, character of the soil, and state of agriculture.

But among all these causes none have so important an influence on determining the climate of a country as latitude and altitude. The degrees of heat are not always equal for the same latitude; thus at Rome, in latitude 63° north, the mean temperature is the same as that of Raleigh, North Carolina, in latitude 36° north.

Lines passing through points on the surface of the earth at which the mean annual temperature is the same, are called *isothermal lines.* These lines do not pass round the earth in a direct course like the parallels of latitude, but they vary so as to assume a tortuous direction.

The *isochimenal lines,* or lines of equal cold, or equal winter, vary much more than the lines of equal summer. The reason why latitude affects the temperature of a climate, is because it varies the obliquity of the sun's rays in relation to the earth. This, however, is not the cause of the difference in the length of day and night at different places.

The following table from Muller shows the length of the longest day for the different latitudes.

Polar Elevation.	*Length of longest day.*
0°	12 hours.
16°44′	13 "
30°48′	14 "
49°22′	16 "
63°23′	20 "
66°32′	24 "
67°23′	1 month.
73°39′	3 "
90°	6 "

Altitude has an important effect on determining the mean temperature on all places, whatever may be their latitude. The temperature diminishes from the surface upwards as far as man has ever ascended, and probably beyond this point to the very limit of the atmosphere. The interior of the earth is supposed to be yet in a fluid state from the effects of heat; the solid outside crust constituting only $\frac{1}{140}$ part of its whole diameter: at 50 to 40 feet below the surface, invariable temperature prevails; that is, there is always an equilibrium, so that the mercury in a thermometer would remain stationary at this depth, whatever might be the temperature above in the open air. This point would be at the surface if the temperature of the air was always the same. The increase of cold upwards from the earth is at the rate of 1° F. for every 100 yards. The *snow line*, or line of perpetual congelation, varies less in proportion to latitude than altitude: thus it will be seen by the table below, that this line is much lower at the equator than in higher latitudes in proportion.

Table of Snow Lines from Muller.

Coast of Norway,	2,340	feet	above	sea	level.
Iceland,	3,042	"	"	"	"
Alps,	8,801	"	"	"	"
Mt. Etna,	9,441	"	"	"	"
Himmalayas,	14,625	"	"	"	"
Mexico,	14,625	"	"	"	"
Quito,	15,600	"	"	"	"

There are three reasons given by Dr. Brande, why the cold increases as we ascend, viz: 1. The absorption of the sun's rays in the denser strata of the atmosphere near the surface of the earth. 2. Radiation of caloric from the earth. 3. The ascending current of air.

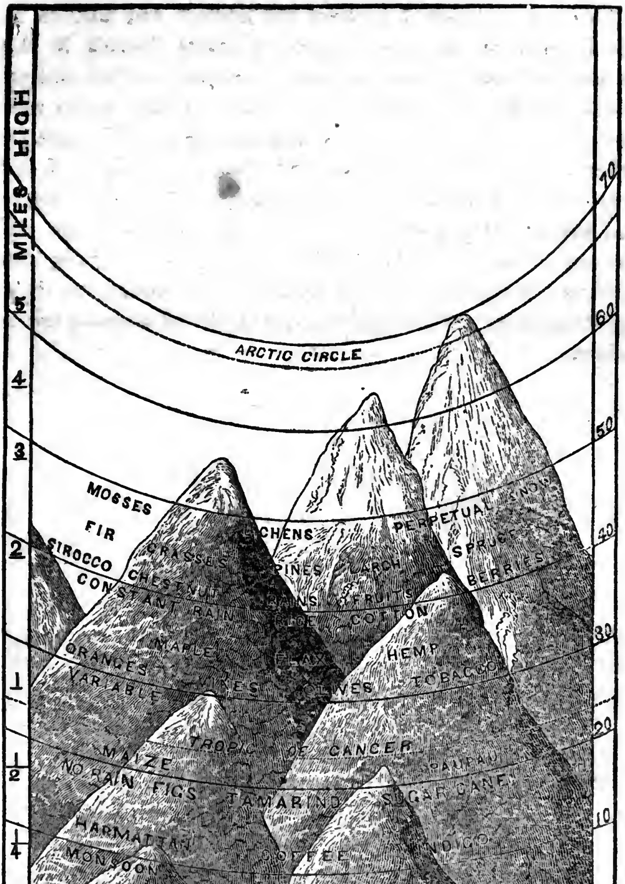
Configuration of the land varies the climate of a country: a plain is hotter than an uneven surface, all other conditions being equal. The sand on the desert plains of Africa sometimes attains a temperature of 122° F. The side of a mountain or hill, which faces the sun, is warmer than the opposite side, for the plain reason that its rays strike upon it more vertically.

Proximity or distance from the ocean is another cause which varies climate. Small islands and peninsulas have milder winters and fresher summers than the interior of continents in the same latitude.

The refrigerating effect of *winds* blowing from the polar seas is felt in countries at great distances: the reverberation of winds among mountains also increases the cold and heat of certain localities. The other causes upon which climate is dependent, are considered in another place. The following table from Muller, shows the mean temperature of several different places.

Table showing the mean temperature of several places during several years,—part of one from Muller's Phys. and Me'ty.

PLACES.	*Latitude.*	*Longitude E. and W. of Greenwich.*	*Elevation above sea level in feet.*	*The whole year.*	*Winter.*	*Spring.*	*Summer.*	*Autumn.*	*Coldest month.*	*Hottest month.*
	North.									
Melville Island,	74°47′	112°0′W.		1,75	28,2	3,1	37,1	0,4	35,8 Feb.	5,8 July.
North Cape,	71 10	25 26		32,1	23,8	29,6	43,4	31,9	5,5 Jan'y.	8,1 July.
St. Petersburgh,	59 56	30 25		38,2	16,9	35,1	60,2	40,3	10,3	16,9
Edinburgh,	55 57	36 W.	286	47,6	38,8	46,9	58,	48,1	2,9	15,0
Geneva,	46 12	6 15E.	1287	49,3	34,2	49,1	64,2	50,2	0,4	18,6
Vienna,	48 13	16 29	507	50,1	32,2	51,	68,3	51,	1,6	20,7
London,	51 31	0 0	299	50,9	39,4	49,1	62,7	51,2	3,0	17,8
Paris,	48 50	2 26	208	51,3	38,	51,8	64,5	52,1	1,8	18,9
Baltimore,	39 17	W7 636		53,	32,9	51,9	73,5	55,2	0,6	24,0
Rome,	41 54	12 34E.	234	59,9	46,5	57,3	73,2	61,9	7,2	23,9
Mexico,	19 26	99 W.		62,	55,4	64,5	66,3	61,2	12,3	19,7 June.
Algiers,	36 47	2 69		64,1	54,4	63,	74,6	70,4	14,5 March.	24,7 Aug.
	South.									
Cape of Good Hope,	33 55	18 18E.		66,3	58,4	65,6	74,4	67,	14,3 Aug.	24,4 Jan'y.
	North.									
Calcutta,	22 35	88 26		83,2	67,9	82,5	83,2	79,1	18,4 Jan'y.	29,9 May.
Jamaica,	17 50	77 55W		79,	76,2	78,7	81,4	80,	24,4	27,7 July.
Madras,	13 5	80 21E.		82,1	76,4	83,6	86,2	81,5	24,1	31,3 June.


MILES HIGH
5
4
3
2
1
1/2
1/4
70
60
50
40
30
20
10
ARCTIC CIRCLE
MOSSES
FIR
SIROCCO
CONSTANT RAIN
LICHENS
PERPETUAL SNOW
SPRUCE
BERRIES
GRASSES
CHESTNUT
PINES
LARCH
GRAINS
FRUITS
RICE
COTTON
MAPLE
FLAX
HEMP
ORANGES
VARIABLE
VINES
OLIVES
TOBACCO
TROPIC OF CANCER
MAIZE
NO RAIN
FIGS
TAMARIND
SUGAR CANE
HARMATTAN
MONSOON
COFFEE
INDIGO
SPICES
BANNANAS
TRADE WIND
SEA LEVEL
EQUATOR

EXPLANATION OF THE CUT.

This cut is designed to show the latitude and altitude at which some of the most important plants flourish in the greatest perfection. It shows also the latitude in which various winds prevail,—the latitude where there is little or no rain and also where there is almost constant rain. The scale of miles on the left hand of the cut shows the height of the mountains, the elevation at which plants grow on their sides, and the line of perpetual snow. On the right hand are the degrees of latitude. The locality of plants, as shown by the table, are not perhaps strictly accurate in all cases; but they approximate correctness sufficiently near for all ordinary calculations.

INFLUENCE OF AGRICULTURE ON THE CLIMATE AND THE ANNUAL FALL OF RAIN.

The question, whether the clearing away of forests and the labors of the agriculturalist have had any influence in lessening the annual quantity of rain and the quantity of water in streams, as well as in modifying the climate, is one of considerable interest and importance. The clearing away of forests, so as to allow of free evaporation of water from marshes, and permit the access of the sun's rays to the soil, most certainly has a tendency to equalize the distribution of heat, if it does not actually raise the mean annual temperature. The mean temperature of the whole earth, however, was much higher formerly than at present. The tillage of the soil, by rendering it loose, and exposing a greater surface to the action of heat and air, favors evaporation, and in this way makes a cold, wet soil, dry and warm. It also increases the capacity of the soil for heat, and favors nocturnal radiation and the formation of dew: but perhaps this fact goes about as far to sustain one side of the question as the other.

It is a fact universally admitted by geologists, that the level of the waters of the earth have every where undergone a change. The instances are numerous, in which rivers, lakes, seas and marshes, have been greatly diminished or totally dried up; this may be one of those phenomena which is evident to all, but which is nevertheless difficult clearly to explain. Islands have risen out of the sea, coasts have been left dry by the receding of the waters, and the beds of large rivers have become dry arable soil. This has of course been in some instances owing to the actual elevation of portions of land by some subterranean force: and it is also true that portions have been submerged by similar causes. But these causes are insufficient to account for the general drying of streams and diminution of rains in cleared agricultural districts. "In felling the trees which covered the crowns and slopes of mountains, men in all climates seem to be bringing upon future generations two calamities at once,—a want of fuel and a scarcity of water."—[Humboldt.]

The rainy season is less regular in countries where the soil is dry and naked, than where it is moist and covered with dense forests or luxuriant vegetation. In some parts of South America, which are clothed with ancient and large forests, rain is falling almost incessantly: but in the same country, where there are wide extended plains and little vegetation, it seldom or never rains. Boussingault states, that when he was in Payta, in South America, the inhabitants informed him it had not rained there in seventeen years. The conclusions to which he arrived on this subject, part of them sustained also by Humboldt and Dr. Hitchcock, are as follows.

1. "That extensive destruction of forests lessens the quantity of running water in a country.

2. "That it is impossible to say precisely whether this diminution is due to a less mean annual quantity of rain, or to more active evaporation, or to these two effects combined.

3. "That the quantity of running water does not appear to have suffered any diminution or change in countries which have known nothing of agricultural improvement.

4. "That independent of preserving running streams, by opposing an obstacle to evaporation, forests economize and regulate their flow.

5. "That agriculture established in a dry country, not covered with forests, dissipates an additional portion of its running water.

6. "That clearings of forest land of limited extent may cause the disappearance of particular springs, without our being therefore authorised to conclude that the mean annual quantity of rain has been diminished.

7. "That in assuming the meteorological data collected in intertropical countries, it may be presumed that clearing off the forests does actually diminish the mean annual quantity of rain which falls."

CHAPTER II.

RAIN.

The philosophical principles upon which the phenomena of rain are immediately dependent, are not yet well settled: rain is supposed, however, by many of the best writers, to depend upon the action of electricity for its origin. All causes which have a tendency to reduce the temperature of the air, cause a precipitation of moisture. When the aqueous vapor which is held in suspension by the air becomes condensed by cold, the minute vesicles coalesce and form drops, which by their gravity descend through the air, which is no longer capable of sustaining them.

The drops of rain are said to be from one twenty fifth to one third of an inch in diameter: when they descend through a stratum of dry air, they are partly dissipated by evaporation. This accounts in *part* for the fact that there is less rain on plains than on mountains.

The same latitudes have not the same quantity of rain: this, like climate, is modified by various local circumstances,—as altitude, proximity to the sea, direction and prevalence of winds, agricultural condition, forests, &c. The quantity of rain which falls during the year is greatest at the equator, and diminishes as we leave this point and approach the poles.

The quantity also which falls during the night and during the day, varies at different places: in Europe more rain falls during the day than during the night time; while in South

America more falls during night than during day. The mean quantity of rain is less as we ascend above the sea level: it is more in the same latitudes where the mean temperature is 68° F., than at any point above or below this.

Rains become less periodical and regular as we leave the equator. The mean annual quantity of rain in Europe, between latitudes 35° and 50° north, (and probably the same would be nearly true of similar latitudes in the United States,) is from 25 to 45 inches.

The mean quantity, as shown by the report of the Regents of the University of New York to the Legislature, for the last ten or fifteen years, as measured at thirty different places in this state, is 35.84 inches. Of these various estimates, 43.65 was the greatest number of inches,—which fell at "Erasmus Hall," Long Island: the smallest number was 28.14, which fell in St. Lawrence county. We see from tables in Boussingault's work, that most falls in autumn and least in spring: we see also that most falls in July and least in March of any months in the year.

This table is from the record kept by L. Wetherell, Esq., at the Rochester Collegiate Institute.

Greatest annual mean temperature for 13 years, ending with 1847,	39°99	
Least do.	25 46	
Greatest mean temperature of one year,	48 66	
Least " " "	43 71	
Highest heat, July, 1845,	102	
Lowest " Feb., 1836, 8° below zero.		
Most rain in one month, Oct., 1846,	6.79	inches.
Least " " " " Jan., 1837,	0.16	"

DEW AND FROST.

All bodies in nature are constantly undergoing a change of temperature: however hot or cold a body may be, it is continually giving out heat, either by *radiation* or by *contact*, or it is receiving and absorbing heat from other bodies. Upon the principle that heat tends to seek an equilibrium, by means of radiation and absorption among bodies, the production of *dew* and *frost* may be accounted for.

During the absence of the sun, a great quantity of heat is dissipated from the surface of the earth by radiation: by this means, when the night is clear, the temperature is considerably lowered: when, however, the earth is overhung by a canopy of clouds, they radiate in return, or reflect, and thus maintain an almost uniform temperature. When the clouds are absent, all the heat radiated by the earth is lost in the upper regions of space, and the surface is reduced in temperature many degrees below the atmosphere.

"The stratum of air which lies in contact with the surface of the ground is then cooled by *contact*, and a portion of the watery vapor which it had possessed in the elastic form, is deposited as liquid water. If the temperature of the air be itself low, and the night very clear, the cooling may proceed so far that the drops of dew at the moment of their deposition shall be frozen, and thus form frost."—[Kane.] The fact is familiar to most observers, that dew and frost are formed only in clear starlight and still nights,—and then only on the surface of good radiators.

The cooling of the earth's surface by the loss of radiant heat, is prevented by a covering of snow or any other substance which intercepts its passage, and no dew or frost is formed. Thus plants may be protected against frost by covering them with a blanket or layer of straw: the same end may be attained by raising large fires by means of damp straw, brush, &c., so as to destroy the transparency of the air by a cloud of smoke and watery vapor. This mode is practiced by the Incas of South America, who seem to understand the conditions under which dew and frost are formed. When there is a current of air, there will be no condensation of watery vapor so as to form dew or frost: hence they are seldom or never seen on a windy night.

In some parts of the world, as in sections of South America and Mexico, dews are so copious as to supply the place of rains. The cold ascribed by many persons to the light of the moon, is nothing but the consequence of nocturnal radiation. *Mists, fogs,* and *clouds,* are only floating vesicles of watery vapor, which obscure the transparency of the atmosphere; they differ only in the degree of their density. "A fog, [says a celebrated naturalist,] is a cloud in which one is,—a cloud is a fog in which one is not." Fogs are not common in hot countries,—they rise to a small height, and are prevented by winds. In Peru dense fogs continue for half the year. Day fogs are volcanic ashes and vapors diffused through the air by wind. The appearances of clouds may be changed according to their height, density, distance, and the angles at which the sun's light strikes upon them, &c. They are moved about and broken apart by winds, and assume various and beautiful hues, according to the different colors of the sun's rays which they reflect.

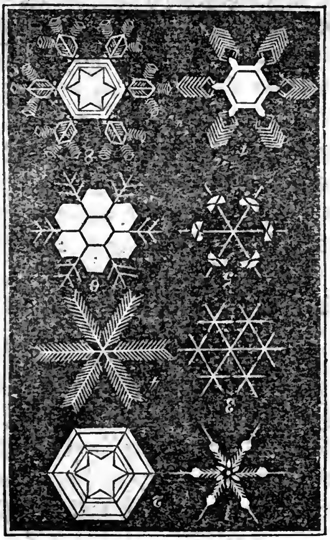
Clouds, then, are merely floating, distant fogs, and are most frequently formed over some body of water or wet soil.

SNOW.

Snow is congealed water, which descends from the upper regions of the atmosphere. The precise conditions of atmosphere requisite for its formation, or the manner in which it takes place, is not yet well understood. The most that is known respecting it, is in relation to the form of its flakes: these are stellate, and composed often of hexagonal prisms, arranged at an angle of 60°, from each of which others frequently shoot out at the same angle. The whiteness of snow is said to depend on the minuteness of its crystals. In some cases snow presents no appearance of crystalization.

Snow recently fallen has a bulk ten or twelve times that of the water from which it is formed; while common ice has a bulk only about one-ninth greater than the water of which it is formed. The temperature of the air in which snow is formed, must be below freezing,—that is, 32° Fah.; and if it falls through a warmer temperature in its descent to the earth, it is melted,—hence there is no snow in warm weather, nor in the torrid zone, except on the summits of mountains which reach above the line of perpetual congelation. It may there snow above and rain below.

The *snow line*, or line of perpetual snow, varies greatly in altitude, according to location and circumstances. On the Himmalaya chain, according to Humboldt, the snow line on the south side is 4,4000 feet below that on the north side; so that this line cannot be depended upon as a point by which to estimate the altitude of mountains.



[This figure from Muller shows a few of the forms of snow flakes or crystals, all of which belong to the hexagonal system.]

HAIL.

Hail is a well known meteor, which occurs most commonly in spring and summer, and is often accompanied with thunder. It is formed by the congelation of rain or vapor in the upper regions of the atmosphere. Hail storms are of rare occurrence, and seldom continue more than a quarter of an hour. Hail clouds always float lower than rain clouds. Hail stones appear to be composed of several spherules adhered together; those of the centre being soft, sometimes nearly fluid water, and those of the circumference solid and opake.

They are also occasionally laminated or radiated. Hail stones are sometimes enormously large: the largest of which we have seen any account, according to Dr. Brande, measured 14 inches in circumference, and weighed from 5 to 13 ounces. Many ingenious speculations have been made to account for the formation of hail, but none of them sufficiently satisfactory to be entitled to implicit belief. The most probable cause of this phenomenon now is, that "hail is produced by the mixture of exceedingly cold air with a body of hot and humid air."

[Olmstead.

Whether a cold wind comes suddenly from the regions of perpetual congelation, in contact with a body of hot air charged with vapor, blows suddenly into the regions of perpetual frost, and thus, by condensation of the vapor, produces hail, we cannot determine. It is sufficient for this theory, that hot moist air meets with intensely cold air in any way whatever.

LIGHTNING.

"This is an electric phenomenon produced by the passage of electricity between one cloud and another, or between a cloud and the earth." The zigzag form of the flash, the frequency of its repetition, and the great length, or extent of sky which it embraces, are not yet well understood or accounted for.

The phenomena of lightning are best observed from the tops of mountains which extend above the clouds; from such a position the flashes have been obsevered to extend for several miles in length. The frequency of succession, and length of the luminous streaks, are supposed to depend upon the imperfect conducting power of the clouds and vapor between them.

The question is now settled, that lightning rods, by conducting off the fluid, serve as a protection to buildings. The rod protects a circle, the diameter of which is four times the length it extends above the highest point of the building: hence the failures of lightning rods have been owing to their not extending sufficiently high.

THUNDER.

The noise produced by the passage of lightning or electricity through the air, from one cloud to another, or from a cloud to the ground, is termed in common language, thunder. The loudness of thunder depends upon the magnitude and proximity of the explosion, the relative position of the clouds, the character of the surrounding country, and the position of the observer.

The sharp crashing noise sometimes heard, is caused by lightning striking near us: the low rumbling noise is the effect of distant thunder: the rattling sound is occasioned by a quick succession of explosions from a highly charged cloud. The same species of snapping noise attends the discharge of sparks from the prime conductor of a charged electrical machine. "And when we consider how trifling a portion of electric matter is put in action by the most powerful means of artificial excitement, compared with the quantity stored up in a full charged thunder cloud, the discrepancy between the appalling crash of the one and the insignificant snap of the other, it will appear surprising that both should originate in the same cause."—[Brande.]

Lightning is the light attendant upon electrical action, and thunder the noise which succeeds it: the difference in time between the two phenomena depends upon the distance of the explosion from the observer, allowing the velocity of sound to be 1,125 feet, and that of light about 200,000 miles in a second of time. We give below an extract from the "Encyclopedia Brittanica," showing the various conditions under which electricity appears in the atmosphere.

"1. In regular thunder clouds.

"2. During fog with small rain.

"3. During a brisk snow or hail storm.

"4. During a smart shower on a hot day.

"5. During a shower on a cold day.

"6. In hot weather after wet days.

"7. In wet weather after dry days.

"8. In clear and frosty weather.

"9. In clear warm weather.

"10. During a cloudy sky.

"11. During a mottled sky.

"12. In sultry weather with light hazy clouds.

"13. In cold, damp nights.

"14. During a north-west wind, which produces a sensation of dryness and coldness, not indicated by the thermometer."

WINDS.

Wind is air put in motion. Rarefaction of one portion of the atmosphere by heat, and condensation of another portion by cold, are the principal causes of wind. Some local causes of limited extent may produce wind,—such as large fires, &c; but these winds are limited to the locality where they originate. There is no known cause, besides heat and cold, which is capable of producing any general or extensive current in the air.

A wind may be merely *relative* or apparent, and proceed from the passage of the observer through the air, as by a steam car or balloon. If the speed of his vehicle be twenty miles an hour, he feels a current of air equal in velocity to his own; the wind appears to blow at that rate. The direction of winds may be modified by various causes: when two or more currents meet from different directions, the general direction will be a *resultant* one, the consequence of the several forces, as in the case of trade winds.

Winds have received various distinctive appellations according to the phenomena which they present: thus we have the *trade winds*, the *land and sea breezes*, the *harmattan*, the *monsoon*, the *simoon*, the *sirocco, whirlwind, hurricane* and *tornado.* A brief description only of each of these varieties can here be given.

Land and sea breezes.—These winds prevail mostly among the islands of the torrid zone; but more or less in all maritime countries. They are mild, balmy breezes, which blow towards the shores during the day, and from off the land towards the sea during the night time. Their phenomena is explained as follows: during the day the land becomes heated by the rays of the sun,—the heat of the ground rarifies the air, which consequently rises to the higher regions, while the cold air from off the ocean rushes in to supply its place; thus producing a breeze inland as long as the sun continues to warm the earth. This is called the *sea breeze.*

During the absence of the sun, the earth, which radiates its accumulated heat faster than the sea, becomes cooler, and the direction of the breeze is changed: the air from off the ocean rises, while the colder air from the land rushes in to supply its place, just as in the case of the sea breeze. This night wind which blows off the land is called the *land breeze.* As the central part of an island becomes warmer than its shores, the breeze will be the strongest in the midland: "its current will also be performed in a constant *gyration;* so that the air which flows in upon the land by day, rises, flows out above, and returns again in the same current: and the process is similar by night, only the current is reversed." At the time when a perfect equilibrium exists between the temperature of the land and sea, the wind ceases, and there is for a time a dead calm.

Trade winds are produced by the same causes operating upon a larger scale, and the revolution of the earth on its own axis. These are tropical winds, which prevail only within the limit of about 30° each side of the equator. Their general course on the north side of the equator, is from north-east to south-west,—and on the south side, from south-east to north-west. The upward current of the air at the equator, in consequence of its higher temperature, causes the colder air to rush in from the north and south towards the point of greater rarefaction; this produces the northward and southward currents. These currents have now a westerly tendency given them by the diurnal rotation of the earth on its axis towards the east; thus producing their general directions as above described. When not changed by local causes, their direction is the same throughout the year: but however they may be modified, they always blow towards the point of greatest rarefaction, and receive a relative motion from the earth's diurnal revolution. Their velocity is greatest at the equator, where the earth's motion is the most rapid, and diminishes towards the poles in proportion as the circumference of the earth diminishes, and the motion is less rapid.

The *harmattan* wind is a periodical easterly wind, which blows irregulary in Africa: it occurs three or four times yearly, and continues for a longer or shorter period, according to circumstances. It blows with only a moderate velocity, is peculiarly dry and unpleasant: it is attended by a haziness of the atmosphere, which often obscures the sun most of the day. During this wind there is no moisture in the air, and no dew or fog; vegetation becomes parched, and droops. Notwithstanding the depressing and disagreeable effects of the harmattan, it is said to be a salubrious wind.

Monsoons are a modification of the trade winds, which occur mostly in the Indian ocean, and north of 10° south latitude. The south-east winds blow from April to October, and are frequently attended by rain: from October to April they blow from the north-east, and are dry. The change from one monsoon to another is usually attended by violent storms.

The *simoon* is a hot, pestilential wind, which, during certain seasons of the year, blows northward from the deserts of Africa and Arabia. This wind, after being modified by passing over the Mediterranean sea, is called in the south of Italy, the *sirocco;* its poisonous effects are supposed to depend on its dryness.

Whirlwinds are such as have a rapid gyratory, as well as progressive motion. *Hurricanes* are generally whirlwinds confined to a narrow path, with a forward motion, sometimes not exceeding 15 miles an hour.

A wind which moves at the rate of 4 or 5 miles an hour is called a *gentle breeze;* when its velocity is 15 or 20 miles an hour, it is *a gale;* when 30 to 40 miles an hour, a high wind; and when 100 miles an hour, a hurricane or *tornado,* Hurricanes are more frequent on the shores of China and the Indies than in any other part of the world.

CHAPTER III.

AURORA BOREALIS.

"This is a luminous meteor usually appearing in the northern part of the sky, and presenting a light somewhat resembling the dawn or break of day." The aurora exhibits such a variety of forms at different times, that no general description can give any definite idea of its appearance: this, however, may be easily attained by observation of the meteor itself. It appears to be a horizontal cloud extending towards the east and west, and rising a few degrees above the horizon. The lower part of the cloud is often darkish, and the upper part luminous and whitish: from this part, streams or columns of light shoot upwards with an unsteady, wave-like motion, reaching sometimes to the zenith, and at others only a few degrees above the horizon.

The "Northern Lights" usually appear two or three hours, or soon after sunset, and continue a few hours, and occasionally the whole night: they also sometimes appear for several successive nights, but are rarely seen after midnight or in the morning.—[Brande.] They often succeed a change of weather from heat and rain to cold and clear. They are sometimes tinged with green or orange, but more commonly with various shades of red. The aurora is sometimes seen in the southern hemisphere. The mean height of the luminous sheet has been variously estimated at from 100 to 400 miles. No satisfactory explanation of this phenomenon has yet been given; many ingenious theories have been proposed, but as we have not space to detail them for the gratification of the curious, we must refer them to larger and more scientific treatises. The probable cause, however, is electricity.

IGNUS FATUUS, OR "WILL O' THE WISP."

This is a nocturnal light, commonly known in this country by the name of "*Jack-Lantern:*" it is seen floating over marshy grounds, moors, grave yards, and along the margins of rivers, and sometimes has a progressive motion, which is probably given it by the passing breezes. The origin and nature of this meteor have been the subject of many superstitious theories and absurd speculations; it has often been ascribed to supernatural causes. The most probable explanation of it is that given by Muller: he supposes it to be hydrogen gas which is mixed with phosphorus; and that consequently it is nothing more than a phosphorescent light.

A HALO,

Is a luminous circle, usually of various and beautiful hues, surrounding the sun or moon during certain conditions of the atmosphere. There are two kinds of halo, depending upon different physical causes. The first are small, their diameter, according to Dr. Brande, not exceeding from 5° to 10°, and composed of three or more concentric rings of different colors. "These are usually called *coronæ;* and they appear either when a small quantity of aqueous vapor is diffused through the atmosphere, or when light fleecy clouds pass over the sun or moon." The second kind consists of a single luminous circle whose diameter is about 45°.

A halo of the moon is usually a white circle with its inner edge sometimes tinged with pale red. There is much truth in the remark, that a dense halo close to the moon portends rain. Lunar halos are most frequent, because the sun's rays are too dazzling to admit of their being seen. The most probable cause of this phenomena is, that it depends on the refraction of light in passing through small transparent prisms of ice, floating in the higher regions of the atmosphere.

PARHELIA.

Parhelia, or mock suns, consist of the simultaneous appearance of several images of the true sun. They are at the same height above the horizon as the sun, and are connected by a horizontal circle, which is sometimes colored, but usually white. The cause of these suns is not satisfactorily explained: they are supposed, however, to depend in some way upon the reflection and refraction of the sun's rays. There may be parhelia without rings, and rings without parhelia. They never appear in an unclouded sky,—sometimes occur opposite to the sun.

FIRE BALLS.

These are "luminous bodies which suddenly appear in the sky, usually at a great height above the earth, and shoot through the heavens with immense velocity, and are sometimes accompanied by the fall of an aerolite." Various hypotheses have been proposed to account for these meteors: limit does not admit of a detail of these opinions; and it is perhaps sufficient to say, that the true explanation of this phenomenon has not, so far as we can ascertain, been given.

RAINBOW.

This well known and beautiful meteor consists of two concentric arches, formed of the colors of the solar spectrum. It is caused by the refraction and reflection of the sun's rays while falling on drops of rain. The size of a rainbow depends upon the height of the sun above the horizon. *Inverted* bows are sometimes seen on the ground; they are formed by the rays of the sun falling on the drops of dew or rain which are suspended from the tops of grass, or from spider' webs: they are also seen about waterfalls and ship masts, forming a perfect circle. Lunar rainbows are sometimes seen in the night time; but their colors are faint and indistinct. In order to see a rainbow, we must face a cloud and turn our back to the sun or moon. The philosophical explanation of rainbows will be found in works on natural philosophy and meteorology.

MIRAGE.

Mirage is an optical illusion often observed at sea, especially in high latitudes; it sometimes also appears on the land, particularly in Egypt and Persia: it is seen also on the margins of rivers and lakes. It consists in the appearance in the air over the surface of the sea, of multiplied images of objects on the surrounding coast.

"It arises from unequal refraction in the lower strata of the atmosphere, and causes remote objects to be seen double, as if suspended in the air." These images are sometimes inverted: ships, whale fisheries, and other objects, are sometimes descried by means of mirage at considerable distances. The mathematical theory of this phenomenon will be found in works on optics, &c.

SHOOTING STARS.

These are common and well known meteors, some of which resemble fire balls in every respect. We shall not attempt any description or explanation of them, as their origin and nature are involved in great obscurity and uncertainty.

AEROLITES.

These are mineral masses which fall to the earth apparently from the upper regions of the atmosphere. They have a dark or blackish color externally and a grayish hue internally. They have a specific gravity more than three times that of water: chemical analysis of one specimen shows its constituent elements to be, iron, sulphur, silex, nickel, magnesia, and sometimes chromium. These meteors have, with some probability, been supposed to come from volcanoes in the moon: but there is still great obscurity hanging about the whole subject.

COLOR OF THE SKY.

The general color of the unclouded sky is azure or blue: this is explained on the supposition that the particles of the atmosphere, when illuminated, reflect mostly the blue rays. Whenever the prevailing color of the sky is anything but a pure blue, it is discolored by smoke, vapor and clouds; the more dense these clouds, the nearer the color of the sky approaches to black. The deep red of the morning and evening sky is explained by supposing the atmosphere permits only the red and yellow rays to pass, and reflects the blue rays.—[Muller.]

The fiery red of morning is caused by an excess of moisture, which, notwithstanding the tendency of the sun's rays to disperse it, forms clouds in the atmosphere, and hence indicates rain. A gray sky at morning and a red sky at evening, on the contrary, foretell fine weather. The various other beautiful hues which tint the sky and fringe the massive clouds, so as to produce all the varied gorgeous drapery of the heavens, are caused by the absorption, refraction and reflection of the different rays of the solar spectrum.

TWILIGHT.

Twilight is the diminished light of day, which is seen from the setting of the sun on its sinking below the western horizon, till the last faint gleaming of day has disappeared. The time at which twilight begins and ends, is altogether arbitrary, and must depend very much on the acuteness of the vision of the observer. It has been said to commence at the moment of sunset, and terminate when the first small stars are visible. Twilight is short in countries having a pure sky: in Chili, it lasts only a few minutes. In high latitudes it is of longer duration, on account of the sun's orbit being much inclined to the horizon. In countries lying in the vicinity of 50° of latitude, twilight continues until the sun has descended from 15° to 20° below the horizon.

The *moon's light* is only the reflected light of the sun, and is estimated to be, when in its greatest intensity, only $\frac{1}{1000000}$ part as much as the light of that vast luminary.

PART V.

AGRICULTURE.

CHAPTER I.

FORMATION AND ELEMENTS OF SOILS.

THE soil is composed of disintegrated rocks, animal and vegetable matters: most soils are made up of successive layers of fine sand and organic matters, loam, fine gravel, clay, coarse gravel, and occasional masses of rock of various sizes. Various causes have concurred to produce the alluvial deposit on the surface of the earth, which must ultimately have been formed entirely of the rocks which constitute the solid basis and principal bulk of the globe.

The running water of rivers and the great ocean current which sweeps across the earth had denuded the rocks which it washed in its course from the high lands to the plains and valleys: in this way, ravines have been excavated, valleys filled up, and vast level plains formed. The floods formed by rains, and the torrents resulting from melted snow and ice, which flow down the mountains' sides, wash away all loose matters, and often undermine and tear away fragments of rock: these are swept along by the impetuous stream, their corners worn off, and they, together with the finer particles, are deposited on the plains or in the valleys, in the form of sand, gravel and "boulders."

The action of the air contributes powerfully to the decomposition and crumbling of rocks. Water, also, which falls into the cleavage or crevices of rocks, and becomes frozen, often cleaves large masses asunder by its expansion in passing into ice: these masses are again subdivided in the same manner, until entire hills of marble, slate, and other rocks, are completely pulverized. The affinity of the gases of the air and water for these elements of the various rocks produce the same effect. The combined action of ice and water in transporting masses of rock is another powerful agency in the formation and distribution of soils. Immense blocks of rocks are frequently frozen into ice, which is subsequently broken up and floated by streams and freshets to great distances from their original locality: these, in process of time, become pulverized, and add their elements to the soil.

The action of fire in volcanic districts produces immense effects in chaging the character of rocks, leveling hills, and filling up valleys with ashes and lava: so vast is the quantity sometimes thrown out at a single eruption, that the whole country for many miles around is covered with the melted rocks, scoria, ashes and cinders.

In this way Pompeii, Herculaneum and Stabia were inhumed A. D. 79, by a single eruption of Vesuvius. Whole strata of rocks are sometimes broken up by earthquakes, and are afterwards disintegrated and mingled with the soil. The agency of winds in wafting fine particles of alluvium and sand has in many places entirely changed the character of the soil; in some places vast barren plains have been formed, "dunes" or sand hills raised, fertile fields stript of alluvium, and others coveted by sand containing no other elements of a fertile soil.

It is apparent now, that the soil bears no necessary resemblance in all cases to the rocks on which it lies, except when derived directly from them; then it partakes of their nature.

After the surface of rocks has by these agencies become sufficiently pulverized and decomposed to form a thin layer of soil, lichens and mosses succeed in fixing their roots in it, causing at the same time further disintegration of the rocks, and increase of the soil by their annual decay. When the soil becomes in this way of sufficient depth and fertility to nourish other, larger, and more perfect species of plants, vegetation becomes more abundant: the decay of this, together with the organic and earthy matters of animals, which are returned to the soil, combined with the art and industry of man,—a soil sufficiently deep and fertile for successful cultivation, is in process of time produced.

A general knowledge of the rocks, metals and earths, is of great value to the agriculturist, in enabling him, by the indications which they afford, to discover springs, mineral waters, ores, mines of coal or metal, marl, lime, valuable stones, &c.; and also to direct him to the best locations for lime kilns, glass houses, brick kilns, potteries, foundries, salt works, bath houses and stone quarries. Modern chemistry has shown that almost every substance is a compound of several others,—and future experiment may yet show us the compound nature of many bodies which are now considered elementary. There would be little difficulty in determining the character of any soil, had we only to consider the constitution of the rock from which it was originally derived.

But, during the lapse of ages, the various causes which have been in operation have so changed them that their primitive character has almost disappeared, and they must be considered in their present actual conditions. Arable soils consist mainly of silex and alumina, with some lime, iron, sodium, potassium, manganese, magnesia, animal and vegetable remains in various proportions and different stages of decomposition. The elements of the soil must exist in different proportions, in order to render them available for agricultural purposes.

CHAPTER II.

METALS, METALLOIDS, AND ORGANIC ELEMENTS OF SOILS.

SILICON.*

SILICON is one of the most abundant and widely distributed substances, constituting probably one sixth of the entire mineral weight of the globe. It is never found pure or in an uncombined state, but always combined with oxygen, forming oxide of silicon, or silicic acid. The vast mountains of granite, gneiss, porphyry and sandstone,—mica, feldspar, crystal quartz, nearly all precious stones, the sands of the sea shore and desert, and all stones that emit sparks on being struck by steel, are mainly silicon.

It is contained in a crystaline state in the outside bark of many plants, particularly in cane, bamboos and the grasses. It is with difficulty separated from its oxygen,—but when separated and pure, it is a fine whitish powder, destitute of taste or odor: it undergoes no change, except becoming darker and denser, by any common degree of heat, but melts before the blow pipe into colorless glass; it has no affinity for pure water, so that it is not dissolved in it in the smallest degree; it absorbs

* Recent investigations appear to show that silicon is neither a metal nor a metalloid.

water slowly, and allows it to escape easily. It is neither dissolved nor acted upon by any acid except the fluoric,—with which it unites and forms a fluoride of silicon.

The equivalent number of silicon is 22.22,—its specific gravity 2.66. The fixed alkalies easily unite with silicon, and form silicates, as the silicate of potash, lime, &c. It forms an important ingredient in porcelain, glass, and the enamel or glazing of stone ware. The salts of silicon are not numerous; they are all insoluble in water, (according to Prof. Johnston,) except those of potash and soda.

As silicon is so important an element in plants, and so invariably present in all productive soils, a knowledge of its chemical character, and the best means of rendering it available to the roots of growing vegetation, is indispensable.

ALUMINUM.

This metallic earth is found in greater abundance in nature than lime, being one of the principal ingredients in nearly all rocks, except the purest limestone: it is the principal element of clay, and exists largely in garnet, albite and mica: it is found also in the ashes of most plants. In its native state it is usually found in combination with silica, and sometimes with sulphuric or phosphoric acid: it is also found nearly pure, or uncombined, in the ruby and sapphire, two beautiful precious stones. Alumina is an oxide, and the only one known of the earth aluminum; it is white, tasteless and inodorous; its equivalent number is 13.7.

It dissolves in acids and in solutions of caustic alkalies; it has a strong tendency to unite with organic matters, and has also a greater affinity for water than any of the other elementary earths. When mixed with silica in the proportion to form clay, it is easily molded into any form, as in stone and earthen ware: it loses part of its tenacity by fire,—hence the benefit of burning clay soils. Alum is a salt formed by the union of potash, alumina and sulphuric acid,—this salt is extensively used as a mordant in calico printing. Alumina is supposed to contribute but little to the nourishment of plants: it is said by Liebig to be an absorbent of ammonia: this, however, is doubted by Prof. Johnston. Its principal agency as an element of soils, is of a mechanical kind. The salts of alumina are few; they have not been sufficiently tested as fertilizers to determine precisely their value in this respect: Sprengel considers them highly deserving of trial in practical agriculture.

MANGANESE.

This metal is diffused widely through nature, although not in great abundance: it is found mostly in the mineral,—but traces of it also exist in the animal and vegetable kingdoms. It has a very strong affinity for oxygen, and is therefore with difficulty reduced from its oxides and ores,—which, however, may be done by a long continued and intense heat.

It is hard, brittle, granular, grayish white, and has a specific gravity of 8: it is very infusible, soon tarnishes by the absorption of oxygen, and after a while falls into a black powder. There are several oxides, two acids, and many salts of manganese, some of which are soluble and others insoluble in water. It is used in the arts, and is probably a necessary ingredient in soils. Its equivalent is 27.67.

IRON.

This is the most important of all the metals, and is the most extensively distributed over the earth. It is sometimes found in loose blocks of pure metal on the surface; but mostly in veins and mines, combined with sulphur, forming a gold colored ore, called sulphuret of iron,—and with oxygen in the form of the black and red oxides: it is also extensively combined with carbonic acid, constituting the clay iron ore. Native arsenites, phosphates, sulphates and other salts have been found.

Nearly all reddish soils and stones are colored by oxide of iron. Pure iron is bluish white, brilliant malleable and ductile, the strongest of all metals, and has a specific gravity of 7.8; its equivalent is 27.14.

Iron oxidizes readily when in contact with moisture, and also by heat. Only two of the oxides are of any interest to the agriculturist, viz: the black and the red. The black oxide rarely occurs in the soil, except in combination with some acid; and this, when exposed to the air, absorbs oxygen and changes to the red oxide. When the black oxide or sulphate is present in moist boggy soils, it proves injurious to vegetation: the red is less injurious. Both are insoluble in pure water, and both are soluble in acids. The red oxide is said to absorb ammonia from the atmosphere, and by thus bringing it within the reach of plants, it is in this way useful, when the soil contains any considerable quantity.

A red soil containing much iron should be turned over frequently, so as to keep it pervious to the air; and, according to Johnston, such soil "may occasionally be summer fallowed with advantage, in order that the oxide may absorb from the air those volatile substances which are likely to prove beneficial to the growth of future crops."

The sulphate of iron (green vitriol,) is often found in soils, particularly in bogs and marshy places, and it is said to be very injurious to vegetation: these effects are counteracted by lime, marl, and plaster, which decompose the sulphate and unite with the sulphuric acid and form gypsum. In this way it is beneficial to soils containing lime, and may be used as a manure. Iron is found in the ashes of nearly all plants, and to a small extent in animal bodies. It is probable that some of the soluble salts of iron are requisite to the growth of most plants.

SODIUM.

Sodium exists in vast quantities, and is widely diffused through nature: it is found combined with chlorine, forming common salt, of which great quantities are found in Poland, England and elsewhere. It is the principal saline ingredient in the waters of salt lakes and the ocean. It is found in many minerals, most plants, and in all the animal fluids. Sodium is found in vast quantities in South America in the form of a nitrate.

The pure metal sodium is lighter than water, its specific gravity being 0.972; its equivalent number is 23.3. It is a silvery white metal, resembling potassium closely in its appearance. The compounds of sodium are numerous and important. This metal is soft at common temperatures, melts at 194° F., and oxidizes rapidly in the open air.

As soda exists in most soils, and is found in some form in most if not all plants, it is probably a necessaay ingredient in soils; many of its salts, particularly the nitrate, sulphate, chloride and phosphate, are valuable fertilizers.

POTASSIUM.

This is the metallic basis of potash: it is bluish white when not exposed to the air, but by the contact of air it instantly oxidizes and becomes covered by a crust of the alkali, potash: when thrown in water, it takes fire and burns with a violet flame. At common temperatures it is soft and may be molded into any form, like wax: "at 32° it is quite brittle, and crytalizes in cubes; at 70° it is pasty, and at 150°, perfectly liquid. At a dull red heat, it boils, forming a green vapor, and may be distilled."

Like sodium, it is lighter than water; its specific gravity being 0.685. Potassium has a remarkable affinity for oxygen, which it abstracts from almost all other bodies. Its equivalent number is 39.3. Potash is a strong fixed alkali: it neutralizes the strongest acids, and its salts are numerous and important. Potassium is not found in an uncombined and pure state in nature, but in the form of an oxide: it exists in many minerals, nearly all plants, and in animal bodies. It is most abundant in the green and tender parts of plants,—the timber of forest trees contains comparatively little.

Its powerful action on other metals and earths, its caustic action on vegetable substances, and its almost universal presence in soils and vegetation, show it to be an indispensable element of good soils, and a powerful fertilizer. Potash is rendered more caustic by mixture with quick lime,—in this way it is beneficial in compost by facilitating the decomposition of vegetable matters.

MAGNESIUM.

Magnesium is found in the minerals, serpentine, talc, steatite, asbestos, augite, chrysolite and hornblende: it is always found combined with acids, or other earths,—it is found also in marl, and in small quantities in animal substances. It is a white, silver-like metal when pure, malleable, and fusible at a red heat, not changed by dry air, but slowly oxidized by damp air: it dissolves in dilute acids, giving off hydrogen gas, and forming a salt of magnesia.

Its equivalent number is 12.7. When heated to redness in the air, or in oxygen, it burns with brilliancy, and forms magnesia, or oxide of magnesium: it inflames spontaneously in chlorine. It exists in considerable quantity in nature, particularly in magnesian limestone.

Magnesia slowly but entirely neutralizes acids; it is inodorous, white, has a slightly alkaline taste, absorbs and retains water to nearly the same degree as lime, but is less caustic and alkaline. There are several important salts of magnesia, some of which are valuable as fertilizers, and indispensable to the growth of vegetation.

CALCIUM.

Calcium is a white silvery metal, heavier than water,—having a strong affinity for oxygen, with which it combines only in one proportion, forming lime. The equivalent number of calcium is 20.5.

Lime is the most important and abundant of all the earths, being extensively distributed through the mineral kingdom, and constituting the principal earthy ingredient in the shells and bones of animals, and also existing in all plants. It is found in nature combined with carbonic acid, as in marble, limestone and chalk, in quantities so large as to form entire mountains. It is found combined with sulphuric acid, constituting gypsum or plaster of paris: it is also combined with phosphoric, fluoric and arsenic acids.

The minerals, calcareous spar, gypseous spar, arragonite, and many others, are composed of lime. All natural waters contain more or less of this earth. Lime is a pure, white, alkaline earth: when burned lime is exposed to the air, it rapidly absorbs water, and falls into a fine powder, which is called "slaked lime," or hydrate of lime. This earth has a strong affinity for acids, with which it forms several salts. It is only sparingly soluble in water, and less so in hot than in cold water: when completely dissolved in clear water, it is called lime water: this, when exposed to the air, unites with the carbonic acid of the air, and a thin pellicle or layer of carbonate of lime is formed on the surface,—this soon falls to the bottom, and another layer is formed; and so the process continues until the lime all becomes a carbonate, and is thus precipitated from the water.

Lime attacks and destroys both animal tissues and vegetable substances with rapidity, and without the exhalation of those noxious gases and offensive odors, which result when putrefaction goes on without the presence of lime. Lime is valuable as a manure in soils destitute of this earth, by supplying an indispensable element to plants, and also by neutralizing acidity, dissolving silica, and decomposing insoluble organic matters, such as woody fibre, humus, peat, ulmine, &c. The salts of lime are also of great value as fertilizers.

MARL.

Marl is a compound of lime and clay, so intimately mixed that their respective particles cannot be distinguished. The exact process by which nature combines the two elements is not known; for if clay and lime be mixed together artificially, they form a substance quite different from natural marl: and, according to Thaër, "it does not possess the faculty of losing its aggregation when exposed to the influence of the atmosphere, and crumbling to dust like natural marl."

The proportions of the two elements are various: sometimes the lime predominates, sometimes the clay, and in some specimens they are equal. When the clay predominates greatly, it is called clay marl: when the lime predominates, it is called lime marl. Marl is found in considerable variety, both of composition and color: it assumes a blue, red, yellowish or whitish hue, according to the oxides of iron, or other matters which it may contain: it is found in greater or less quantities in almost all countries,—sometimes on or near the surface, and in other cases at considerable depths in the earth.

"It is confined [says Dr. Hitchcock,] to the alluvial and tertiary strata, and differs from many varieties of limestone, only in not being consolidated." It often contains salts of potash and soda, fragments of shells, bones, and some vegetable matter: that which contains a large quantity of shells is called *shell marl:* several other species of marl are described, the most important and valuable of which is *greenstone marl.*

Nearly all the varieties, except stone marl, are easily penetrated and their particles separated by water: frost is also an active agent in pulverizing it,—it is therefore often laid on land at the beginning of winter. Marl may be detected by the acids, with which it effervesces and forms salts. It is evident from the character and composition of marl, that it is a valuable fertilizer, especially on lands deficient in clay and lime.

GYPSUM.

Gypsum is a compound of sulphuric acid, lime and water: it is sometimes found in the form of a soft yellowish white rock, with a texture resembling that of loaf sugar; "but sometimes [says Lyell,] it is entirely composed of lenticular crystals." It is insoluble in acids, and does not effervesce, for the reason that it is already combined with sulphuric acid, for which it has a stronger affinity than for any other. A variety called *anhydrous* gypsum sometimes occurs, which contains no water.

Gypsum is nearly insoluble in pure water;—when deprived of its water by heat, it is called calcined gypsum, or "plaster of paris,"—in this state, if mixed with water, it may be formed into molds or casts, and it soon solidifies into a hard, white, compact mass. When calcined gypsum is long exposed to the air, it absorbs moisture, and is no longer fit for casts and stucco work, until calcined afresh. Gypsum can only be fused by a high degree of heat,—it does not then part with its sulphuric acid, but only loses its water. The origin of this rock is difficult to explain; its found mostly among the new red sandstone, but occurs also among other rocks.

It is found in most countries in great abundance, and in various forms, as *gypseous spar*, *gypseous stalactites* and *stalagmites*, *compact gypsum*, &c., and in combination with clay and lime. Gypsum cannot be formed artificially. Water containing gypsum is called hard water. The decomposition of gypsum can be easily effected by the alkaline carbonates: if powdered gypsum be boiled in a solution of carbonate of potash, a double decomposition, and also reunion, takes palce; the sulphuric acid of the gypsum unites with the potash, and forms sulphate of potash, while the carbonic acid unites with the lime of the gypsum and forms carbonate of lime. Gypsum is one of the most valuable fertilizers known.

CLAY.

Clay is a compound of the two earths, silica and alumina, in a state of chemical union: it usually contains, also, an excess of uncombined silica in the form of sand. Proper clay is formed by nature alone, for no chemical process is known by which silica and alumina can be made to unite so as to form real clay. It is usually colored by some of the oxides of iron, so as to present a bluish, yellow, red or brown hue.

The two elements of clay are rarely contained in equal quantity; the silica almost always predominates,—sometimes to the amount of 93 per cent. Clay sometimes contains an insoluble carbonate or phosphate of iron, which are both thought to be injurious to vegetation. It sometimes contains also manganese and sulphate of iron, the last of which, unless in a limy soil, is injurious to plants: organic matters are often found in clay, giving it a blackish hue and astringent properties. Clay has been formed by the decomposition of rocks, such as granite, feldspar, clay slate and argillaceous schist.

Clay which contains neither iron nor vegetable matter, does not change color by heat: if it contains vegetable matter, it becomes lighter colored by heat; if colored dark by oxide of iron, it may become lighter by burning, on account of the iron changing its proportion of oxygen. White clay, which does not change color by heat, is nearly or quite pure. When clay is dry, it absorbs water rapidly, becomes tenacious and adhesive, so as to retain any form or impression given to it: when saturated with water, it no longer allows that fluid to pass through it: it is from this cause that water stands long on the surface of the ground in swamps having a clay subsoil,—and this is why we find springs and water veins before we come to solid rock.

When wet clay is exposed to frost, it is cracked or fissured, and sometimes completely pulverized, by the expansion of the water it contains, during freezing. It retains water with more tenacity than any other earth, and after being deprived of its water by heat, becomes hard. After being heated to redness, clay loses its ductile properties, is insoluble in water, and is of no use in the soil, until, by long action of the atmosphere, moisture, and animal manure, it is changed to its former condition. Clay does not effervesce with acids, unless it contains lime or carbonate of iron: it requires a high degree of heat for its fusion. Clay is often found in combination with gypsum. There are several varieties of clay, of which we notice only a few.

Kaolin, or porcelain clay, is the purest and finest, and is used in the manufacture of porcelain ware: it is of a yellowish or grayish white hue, and is supposed to be formed by the decomposition of feldspar.

Pipe clay ranks next to kaolin in fineness, and is of various hues.

Bole is a species of red clay, used in the manufacture of brown earthern ware.

Potter's clay is used for bricks and stone ware.

Clay iron ore contains carbonate and phosphate of iron, and has been described under the head of iron.

PEAT.

"Peat usually consists of soluble and insoluble geine, with a mixture of undecomposed vegetable matter and some earths." It is usually limited to the colder parts of the globe: it results mostly from the accumulation and decomposition of mosses, but also from any other vegetable matters which become mixed with it.

The lower stratum of peat beds decays, while the plants on the surface continue to grow, thus adding new matter annually until they attain the thickness, in some cases, of thirty or forty feet. In tropical climates, the heat produces decomposition so speedily that vegetables are resolved into their elements before peat can be formed.

Peat is usually found also in low boggy or marshy districts. According to Dr. McCulloch, "by the long continued action of water and other agents, the geine of peat is changed into bitumen and carbon, which constitute lignite and bituminous coal: in a few instances the process of bitumenization has been found considerably advanced in beds of peat."

Peat is remarkable for its power of preserving animal matters from putrefaction.

The following is an analysis of a specimen of peat from Massachusetts.

Soluble geine,	26.00
Insoluble do.	59.60
Sulphate of Lime,	4.48
Phosphate of do.	0.72
Silicates,	9.20
	100.00

When the decay is far advanced, the peat is a dark colored and sometimes solid mass: when less advanced in decomposition, it is light brown, spongy, and contains pieces of vegetables not yet disorganized,—in this state it is used in some countries as fuel. Peat is sometimes sour, from the presence of phosphoric and acetic acids: it sometimes also contains ammonia; it decomposes slowly in the open air. When mixed with lime or potash and fermenting barn-yard manure, it becomes a valuable fertilizing agent, and may be used on any soil which requires the addition of vegetable matter.

HUMUS.

Humus is a brown or blackish colored substance, composed of vegetable matter in a state of decay. "Humus [says Boussingault,] is the last stage in the putrefaction of vegetable organic matter: its elements have acquired a stability which enables them to resist all fermentation." It is of a spongy texture, easily pulverized, and nearly insoluble in water: it absorbs water with such avidity as to contain three fourths of its own weight without being moist.

Weak acids have little effect on humus, except to dissolve the alkaline and metallic or earthy matters which are usually mixed with it. Potash and soda dissolve humus entirely, with the evolution of ammonia: from this solution, acids cause a precipitate of a brown inflammable powder resembling ulmine. Humus contains more carbon and nitrogen than the vegetables from which it is derived: the nitrogen may be partly formed from the excrements of insects which live in the humus.

Humus contains, besides some mineral elements, carbon, oxygen, hydrogen and nitrogen, phosphoric, sulphuric and humic acids. Humus is dissipated when exposed to the air by a slow combustion, with the disengagement of carbonic acid. This, and all vegetable earths, are entirely destructible. Salts are formed during the decomposition of humus, by the union of bases with the humic acid,—these are called humates.

Besides the above elements, humus contains, according to Berzelius, humic, crenic and apocrenic acids, and traces of glairin. Humus is an indispensable ingredient in all fertile soils, hence the necessity of replacing it in the soil as fast as it is exhausted.

Agriculturists who think to supply the place of manure by frequent and deep ploughing, have been disappointed, and their fields have been gradually impoverished by crops, until they became barren. When humus is put on a clay soil, it is retained with such tenacity by the clay, that the free contact of air is prevented, and it decomposes more slowly,—for this reason clay requires a larger quantity, other things being equal, to produce the same effects, than other soils.

Sand allows free access of air to the humus, which is incorporated with it, and thereby favors its decomposition and consequent fertilizing power. Lime and potash destroy the acidity of sour humus, and favor its decomposition: sour humus contains an insoluble extractive matter, which is injurious to vegetation. A soil which abounds in sour humus produces little but reeds, rushes, flags, sedge, and other poor and unpalatable plants: such soils are rendered fertile by draining, burning and alkalies.

CHAPTER III.

PHYSICAL PROPERTIES OF SOILS.

THE physical properties of soils necessary to be considered are, *density, weight, state of division, firmness and adhesiveness, power of imbibing moisture, power of containing water, power of retaining water, capillary power, contractibility on drying, power of absorbing gaseous matters, power of absorbing heat, power of containing heat,* and *power of radiating heat.*

The *weight* of a soil depends upon its density, or the proximity and density of its particles. Dense soils retain heat longer than light ones, and afford a firmer support to the roots of plants.

The following table, from Johnston, shows the relative weight of several soils.

A cubic foot of dry silicious or calcareous sand weighs				180 lbs.
"	"	Half sand and half clay	"	95
"	"	Of common arable land	"	80 to 90
"	"	Of pure agricultural clay	"	75
"	"	Of rich garden mold	"	70
"	"	Of a peaty soil	"	39 to 50

The *state of division* of the particles composing the soil has an effect upon its weight, as well as money value. A soil composed of clay, sand, coarse and fine gravel and vegetable mold, is superior in all respects to to one composed of either of these ingredients alone.

Firmness and adhesiveness.—Most soils become hard and stiff in some degree, by the cohesion of their particles after being thoroughly wet. Clay soils become hard and difficult to pulverize when thoroughly dried, while pure sand soils scarcely cohere at all. This varies according to the relative amount of sand and clay or lime in the soil. The practical inference is, that a sandy soil is improved by clay, and a stiff clay soil is ameliorated by sand.

The *power of imbibing moisture* is possessed by all fertile soils. In dry weather, this quality in soils is highly important, in order that moisture may be absorbed from the dews of the night, to compensate to the roots of plants what they had lost by exhalations from their leaves and evaporation from the soil, during the day.

During a night of twelve hours, when the air is moist, according to Schubler,

1000 pounds of		perfectly dry quartz sand	will gain	0 lbs.
"	"	Calcareous "	"	2
"	"	Loamy soil	"	21
"	"	Pure agricultural clay	"	27
"	"	Rich peaty soils, still more.		

Power of containing water, in dry climates, constitutes one of the most important characteristics of arable soils. A good soil for ploughing or tilling must be capable of containing from 30 to 70 per cent. of its weight of water: soils which allow their moisture to sink down immediately after rains, below the reach of the roots of plants, are valuable only "for pine plantations or laying down to grass."—[Johnston.]

The following table from Schubler shows the relative capacity of soils for containing water. By this, we mean, the amount of water which a given quantity of earth will imbibe and contain, before it is saturated or full, so as to allow the water to drop or run out.

From 106 lbs. of dry soil, the water will begin to drop, if it be a quartz sand, when it has absorbed		25 lbs.
Calcareous sand,	" " " "	29
Loamy soil,	" " " "	40
English chalk,	" " " "	45
Clay loam,	" " " "	50
Pure clay,	" " " "	70

Power of retaining water.—Evaporation is constantly going on from the surface of the earth, except when the atmosphere is saturated, or rain or dew is falling. The rapidity with which soils become dry after rains, depends upon the tenacity with which they retain water: as a general rule, those soils which are capable of containing the most water, also retain it with the greatest tenacity. Thus a sand soil will lose as much water in one hour as a clay in three, or peat soil in four hours. On this property depends in a great degree the warmth or coldness of a soil.

The *capillary power* of the soil is exhibited by pouring water into the bottom of a flower pot, when it will be seen that the earth gradually takes up the water, and the moisture soon appears on the surface. In the same way the surface soil absorbs moisture from the subsoil; and when this contains an excess of water, the surface is also too wet and cold. Open, porous soils, such as sand, peat and humus, possess greater capillary power than stiff clay. Upon this action the soil is dependent for its supply of moisture during dry weather: upon this, also, the roots of plants are dependent for a supply of soluble saline matters, which, during rains, have been washed down into the subsoil beyond their reach. This is the principal means by which, in hot, dry climates, where rains seldom or never fall, the soil obtains sufficient moisture to produce vegetation. This capillary action explains the existence of the thick crusts of nitrate, carbonate and chloride of soda, which are met with in Peru and other parts of South America, India and Egypt. These salts are brought to the surface by capillary action, in a state of solution, and deposited as the water evaporates.

Contractibility on drying.—Some soils contract or shrink on becoming dried after rains, much more than others; and this appears to be in proportion to their power of retaining water. Thus clay and peat diminish in bulk one fifth on being perfectly dried after saturation, while sand maintains the same bulk in either state.—[Johnston.] This contraction in clay soils has a tendency to tear and injure the small and tender roots of plants.

Power of absorbing gaseous matters.—The necessity of free access of air to the soil has already been noticed; and in proportion to the amount of air which is admitted into the soil, will be the oxygen and other gases absorbed and made available to the roots of vegetation. Clays, peat and humus absorb more oxygen than sandy soils; this is due partly to difference in porosity, and partly to the chemical character of each. Besides oxygen, soils absorb carbonic acid, ammonia, nitric acid, and other vapors which contribute to fertility. All soils absorb gaseous substances the most readily when in a moist state; so that dews and showers are of great benefit, in bringing the soil into a condition to extract from the air fresh supplies of the gases.

Power of absorbing heat.—The earth is capable of absorbing heat during sunshine, so as to attain a temperature above the surrounding air. Dark colored, brown and reddish soils absorb heat most rapidly, and become warm the soonest. They also become from three to eight degrees warmer than other colored soils, and by this means they promote the growth of vegetation better than those of other colors. This property gives an additional value to dark soils over light ones, in countries where sunshine is deficient, and in fields which have a northern aspect.

Power of retaining heat.—As heat always tends to seek an equilibrium, it follows that after the sun has disappeared, and his rays cease to shine on a particular part of the earth, the amount of heat which it has absorbed above that of the air is gradually given off again to the latter, until their temperature is equal, or until the air becomes the coldest,—as in frosty nights. A peat soil cools more quickly than clay, and clay more quickly than sand. This difference must have an influence on the growth of crops. In cold, wet soils, the property of *radiating* heat slowly compensates in some degree for the injury done to plants by these conditions. It also prevents the formation of dew and frost, as soon as would otherwise be the case. On the contrary, soils which radiate heat faster promote the formation of dew by becoming cooled below the dew point sooner, and in this way compensate in some small degree for deficiency of rain.

The absorbing, as well as radiating power of the soil, may be increased by a top dressing of soot, charcoal, muck, or some dark colored manure. *The principle of absorption and radiation as dependent upon color, holds true in relation to plants, as well as to soils: and, if all other conditions are favorable, the light colored, (white straw,) crops should be cultivated on dark colored soils, and the dark colored, (green straw,) crops on the light colored soils.**

The study of the mechanical and physical properties of soils is of more importance than has generally been supposed. These have now been discussed as fully as limits would admit, and we conclude the subject by stating finally, what are the *ultimate uses and relations* of the soil to plants.

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* This idea is original with the author, so far as he knows: whether of any value or not, others may judge and decide.

First, the soil serves as the foundation for upholding and giving mechanical support to the vegetable structure.

Secondly, it absorbs light, heat, air and moisture, which are indispensable to healthy vegetation.

Thirdly, it supplies both the organic and inorganic elements required by the plant as food.

Fourthly, it is a chemical laboratory, in which these elements are constantly being prepared to be taken into the plant by its roots.

CHAPTER IV.

TILLAGE.

All operations upon the soil for its improvement and preparation for crops, may be included under the two heads of *tillage* and *stercology*, or *manuring*. *Tillage* includes the operations of *draining, irrigation, paring* and *burning, rotation of crops, fallow, extirpation of weeds and insects, ploughing, ribbing, lapping, laying in beds, scarifying or grubbing, subsoil ploughing, trenching, rolling, harrowing, hoeing, spading,* &c.

The *objects of tillage* are,—1. To loosen the soil and render it permeable to air, water and the roots of plants. 2. To bring up the subsoil and mix it with the surface. 3. To incorporate manures with the soil. 4. To allow free access of the heat and light of the sun. 5. To pulverize the coarse and compact portions. 6. To destroy weeds and insects. 7. To bury green crops designed for manures. 8. To render wet soils dry and arable. 9. To supply a sufficiency of water to dry soils. 10. To fix moveable and light blowing soils. 11. To clear the soil of roots and stones. 12. To cover seeds with soil after sowing.

The following operations are described by Colman, and are, part of them, peculiar to the agriculture of Europe.

Lapping consists in turning a furrow upon an unploughed surface, so that when the field is finished, it is only half ploughed.

Ribbing resembles lapping, except that two furrows, instead of one, are turned upon the same unploughed space.

Stitching or *laying in beds* consists in turning two furrows, back to back, and then ploughing alternately on either side, until the bed is from 5 to 60 feet wide, and leaving deep furrows between all the beds.

Trench ploughing consists in making a deep furrow, by ploughing one furrow directly in another.

Subsoil ploughing consists in breaking up and loosening the subsoil with a plow for that purpose, and without inverting the surface.

Scarifying or *grubbing* differs from harrowing only by being performed with a cultivator or similar instrument, which goes deeper into the earth than the common harrow, for the purpose of pulverizing the soil, and bringing up roots and stones to the surface.

The other operations of tillage need not be described, as they are common and well understood. There can be no question that much of the success of productive agriculture depends upon the perfection of tillage. A perfect tillage requires the combination of patient labor, mechanical implements of the best construction, and skill in the operations.

A poor soil well tilled may produce better crops than a good soil without tillage. Thorough tillage, by mixing and pulverizing the soil sufficiently, is a means of saving manures and greatly increasing the return of the harvest: it is not, however, true, as once supposed, that tillage will supercede the necessity of all manures; it only compensates for part of the manure requisite, and facilitates the operation of that which is applied. The Chinese, and some nations of Europe, have, by a perfect system of tillage, rendered barren soils fertile, and caused fertile soils to yield harvests of almost incredible amount.

IRRIGATION.

Irrigation has been practiced by the Chinese and Egyptians from the remotest antiquity. In countries where rains seldom fall, and the ground becomes dry and parched, irrigation is of immense value. It consists in taking water from lakes, sewers, running streams or reservoirs, and causing it to flow over the land by means of small canals or furrows, then by proper outlets to carry it off again. It is confined, according to Colman and Johnston, almost exclusively to meadow lands.

The benefits of irrigation in a country where rain falls frequently and abundantly, are the same as those of manuring. When the water used holds in suspension any organic matters, they subside while the water remains on the fields, and leave a visible layer of manure on the surface, after the water is drained off. An example of the fertilizing effects of irrigation is seen in the lands along the banks of the Nile and Ganges. But the effects of irrigation with water that contains no organic sediments, must be considered the same as that of rains. Running water furnishes to plants some gasses, which are absorbed, and in this way are beneficial. Crops of young and tender plants should be irrigated by pure water: it may be repeated every two or three weeks when there is any want of rain, and the water be allowed to lie on the field only three or four days. It is thought by English Agriculturists to be injurious to meadows to flood them immediately after mowing.

Warping is a process similar to irrigation: the object of this, however, is more especially to obtain the sediments of muddy streams, &c.; the water should never be allowed in either process to remain on the field until stagnated. Irrigation is most beneficial on land which is well drained beneath, so as to allow the water to penetrate the subsoil, and not stand too long on the surface. Meadow lands are sometimes watered in the winter to prevent the injurious effects of frost upon the roots of the grass. Irrigation is not practiced to much extent in the United States; and the remoteness of many farms from streams, as well as the expense attending the operation, will prevent its universal application, even where it would be beneficial.

PARING AND BURNING.*

Paring and Burning is much practiced in many parts of Europe, particularly in Great Britain; but, so far as we are informed, it is but little practiced in the United States. It is done mostly upon sward, peat and turf soils. The operation consists in removing, with a plow or spade, a slice from the surface, from one to three inches thick: this is piled up in small heaps along with other combustible matters, such as brush, weeds and decayed wood; these, when sufficiently dry, are fired and allowed to smoulder and burn slowly until the whole is reduced to ashes. The ashes are then spread evenly over the surface of the soil. The quantity of ashes which is sometimes obtained in this way at a single burning, is stated by Colman to be 2660 bushels, or about 77 tons per acre.

The benefits of paring and burning are,—1. It disentegrates and reduces to fineness, some stones and hard clay. 2. It destroys insects, with their eggs and larvæ. 3. It reduces vegetable matter to ashes and gases, which are available for the immediate food of a crop of plants. There are some objections to this process, which ought to be stated, as it involves some principles not wholly understood.

One objection is that it consumes too much of the vegetable and organic matters of the soil: another is the amount of labor required in the operation. The benefit however, of paring and burning upon cold, moist, sour, peat and turf soils, is unquestionable. The lime and potash produced, serve to neutralize acids in the soil, and the iron, if it contain any, is brought to a higher degree of oxydation.

On light, sandy, gravelly soils, where vegetation is thin and

* This operation is very little practiced in America.

there is little organic matter present, this practice is injurious. The process of burning, according to Boussingault, ought to cease after the organic matters are reduced to a blackish ash; for when carried beyond this, so that incineration is complete and a red ash is left, it may materially injure, if not render the soil barren.

DRAINING.

The draining of wet lands has become one of the most important branches of mechanical agriculture. An excess of water in the soil prevents the access of air, reduces the temperature, favors the formation of frost, fogs and mildew, and renders tillage difficult or impossible. Soils may be rendered too wet in various ways, as, by the tides of the sea, by the setting back of rivers, by permanent springs in the soil, by small subterranean streams, and by the compact and retentive nature of the soil or subsoil. The advantages of draining, and the various modes by which it is best accomplished, are well described by Johnston and Colman, from whose works the following facts in relation to the operation are derived.

1. It carries off all stagnant water, and gives a ready escape to the excess of what falls in rain. 2. It prevents the ascent of water from below, either by capillary attraction, or springs. 3. It allows the water of rains to penetrate, and find a ready passage from the soil, instead of washing the surface. 4. The descent of water through the soil is followed by fresh air, which occupies the space just left by the water. 5. The soil after thorough draining becomes looser, more friable and easily broken; this is especially true of stubborn clays, which in practice become altogether another soil. 6. By freeing the soil from the excess of water, it becomes warmer, and thereby advances the crop to an earlier harvest: thus it is "*equivalent to a change of climate.*" 7. When the autumn is wet, draining carries off the superabundance of water, and prepares the land for sowing fall crops, which would otherwise be retarded,

or altogether prevented. 8. In its consequences it is equivalent to an actual deepening of the soil. 9. In wet soils, bones, wood-ashes, rape dust, nitrate of soda, and other artificial manures are almost thrown away. 10. He who drains confers a benefit upon his neighbors also. 11. It produces a more salubrious climate, and conduces greatly to the health and moral happiness of the whole population.

Several different modes of draining are practiced in Great Britain, which are worthy of notice—some of them are also known and practiced in the United States. The process of draining by open ditches is the rudest, and was doubtless the first form of draining. Covered drains were next substituted, of various construction. One form of these is made by digging a ditch, and then filling it with straw or faggots, and covering it over with the earth which was thrown out. Another form is excavated so as to taper to a point at the bottom, and having a shoulder left at the height from the bottom which it is desirable to cover the waier-course. This is then covered by an inverted sod, which rests on the shoulders; after which the earth thrown out in excavating is returned, and the surface levelled. Another process is by the mole plow: another by filling the bottom of a ditch with small stones of uniform size. Two other forms, called in England *tile* and *pipe drains,* are constructed by means of tile and pipes made of brick clay, and are said to form water-courses which are both cheap and durable.

FALLOWING.

"By fallowing, it has been known in all ages that the produce of the land was capable of being increased. How is this increase to be accounted for? We speak of leaving the land to rest, but it can really never become wearied of bearing crops. It cannot, through fatigue, lie in need of repose. In what, then, does the efficacy of naked fallowing consist?" (Johnston.)

Some agriculturists reject the practice of fallowing as useless, upon the supposition that all the objects accomplished by it, may be also by the application of manures. The proposal to substitute manures, is of course equivalent to an admission that fallow is beneficial to the soil. Now if any change takes place in the soil while lying in fallow, we must first know what that change is before we can determine whether manures will affect the same change: and in order to know this, we must have an exact analysis of the soil, before the fallowing begins, and at the end of its term; this will show what new elements are formed, and what old ones are decomposed.

If, then, we have a manure which will furnish to the soil all the elements which were formed by chemical action during fallowing, it will fulfil the same indication. But in either case, an analysis of the soil is requisite before the fact can be established: and inasmuch as those who discard fallowing, have made no such analysis, they have made no demonstration of the truth of their position. And until farther facts are developed by chemical experiment, it may be fairly questioned, whether, on all soils, and under all circumstances, fallow can be dispensed with. The benefits to be derived from allowing land to lie in naked fallow are enumerated by Johnston as follows:

1. In strong clay soils, fallow affords opportunity for destroying weeds, which it is difficult to extirpate while the land is continually bearing crops. 2. The weeds and herbage which spring up during summer, afford an abundant crop for green manure: they should be ploughed under before their seeds ripen. 3. Land which is continually cropped, becomes exhausted of certain elements within the depth to which their roots extend. By leaving the soil at rest, the rains which fall and circulate through it, equalize the distribution of the soluble substances which it contains. The water which in dry weather, ascends by capillary attraction from below, brings up saline compounds and deposits them as it evaporates. 4. Some subsoils require to be turned up and exposed to the action of

the air for some time, before they can be safely mixed with the surface soil. 5. The soil often contains more or less organic matter which is *inert*, or decays so slowly as to be almost unavailable to vegetation: by leaving this to decompose and become fitted for the food of plants, the crop which follows will grow more luxuriantly and yield more abundantly. 6. The nitrates, which are very favorable to vegetable growth, are more rapidly formed when the land lies in naked fallow than when covered with crops. 7. The fragments of rocks of various kinds are disintegrated and decomposed faster during fallow than during cropping. 8. The saline and other substances, such as ammonia, magnesia, the nitrates, &c., which are brought down by rains, accumulate in the soil during fallow. 9. The clay, oxide of iron, and organic matter of the soil, have the power of extracting ammonia from the air; and this is the more rapid, the greater the extent of surface which is uncovered and exposed to the passing air. 10. The light soils sometimes become too loose to afford sufficient mechanical support to the roots of crops, and require time to settle together and resume their cohesion and compactness.

No doubt the period usually allowed to land to lie in fallow may in many cases be very much abridged, and in some cases altogether dispensed with. Whenever fallow is beneficial, it must be ascribed to some one or more, if not all the above causes combined.

ROTATION OF CROPS.

By rotation of crops, is implied, the alternate production of different plants in regular succession on the same land. Experience has shown that the same crop cannot be produced successively on the same field for an indefinite period of time.

The grasses and forest trees seem to present an exception to this principle: but it must be observed that the grasses are mowed or pastured down before arriving at maturity,—for, if they were allowed to perfect their growth and ripen their seeds, the same result would follow as in other crops. And with regard to forest trees, it has been observed that where an oak forest has been cut down, a growth of pine will succeed; and where a pine forest has been cleared away, a growth of oak will spring up in its place: where beech and maple are cut, poplar and basswood often succeed them. Thus it appears that the soft and hard woods alternate with each other.

The reason formerly given for the necessity of rotation was, *that all plants throw off certain matters or excrements by their roots, which prove injurious to another crop of the same kind of plants; but which are beneficial rather than injurious to crops of a different kind.*

This beautiful theory originated with the distinguished botanist, Decandolle, and explains, apparently, in an easy and satisfactory manner, all the reasons for the necessity of rotation of crops. The simplicity and high authority of this theory obtained for it, for many years, an unquestioned assent; and the only objection which lies against it now is, that it is not supported by a single fact.

The objections to it are,—1. That plants do not excrete so great an amount of noxious matters as supposed by Decandolle. 2. No evidence exists of their injurious effects upon the plants from which they are excreted. 3. There has been no demonstration of their nutritive effects on other plants.

This theory, then, must be abandoned, and we must look for one which is supported by facts: and if one cause be found adequate to explain all the effects produced, we are not bound to seek for another.

The necessity of rotation does not depend upon there being *too much*, but *too little*, of some particular elements in the soil. (Johnston.) All plants require certain elements for food, and these are indispensible to their growth and maturity: one plant requires them in certain proportions and another requires these and others besides, in quite different proportions.

"If we assume, [says Petzholdt,] that the utility of the rotation of crops depends exclusively upon the circumstance that all cultivated plants withdraw from the soil unequal amounts of certain ingredients for their nutrition, all the observed facts are at once satisfactorily explained, and the possibility of determining the rotation of crops, or of avoiding it altogether, if desirable, made evident."

It is useless to remark, that no plant can vegetate in a soil which does not contain all the elements which it requires for its food. Some species of grass contain, and therefore require for their growth, a large amount of silica: a soil which contains no silica cannot produce them. A soil may contain just enough silica for one crop, but not enough for a second, so that a second could not be produced; but a crop of some other plant requiring much less silica, might be grown upon it as successfully as the grass before.

"A single crop of wheat may deprive the soil so completely of one of its mineral constituents, that another crop of wheat could not grow upon it; and yet this soil may contain abundant mineral constituents for the production of a good crop of clover or turnips." An analysis of a soil and the ashes of plants desired to be produced upon it, will determine *negatively*, whether it is eligible to their growth: but the only *positive* proof is a trial of the crop upon the soil.

All plants draw certain mineral elements from the soil, but do not all equally exhaust its fertility. All knowledge respecting the application of manures, and the adaptation of certain plants to particular soils, is based upon these facts. The necessity for rotation may sometimes be obviated by allowing the land to lie in *fallow* for a year, after which the crop may be successfully repeated. Manuring may also sometimes answer the same purpose; but as a general rule in *practice*, however it may be explained in theory, a judicious rotation is beneficial.

Boussingault states that he saw in South America, fields on which good crops of wheat were said to have been produced annually for more than two centuries; and also that potatoes are cultivated continually on the same soil. It is stated also by Colman, that onions yield more and more abundantly the oftener they are grown on the same field. These statements either contain some hidden fallacy, or they prove that the fields in question contained an inexhaustible amount of the elements necessary to the plants produced; for they do not, nor were they designed to prove, that rotation is unnecessary.

It is unquestionable that a perfect system of agriculture, and the maximum production of all crops, requires a system of alternation, regulated according to circumstances, and in accordance with the principles of Chemistry. A valuable end to be obtained by rotation is the destruction of certain weeds and the insects which inhabit them.

The following table shows a system of rotation which is practiced in Pennsylvania.

First year—	Grass or clover.
Second "	Pasture.
Third "	Indian corn.
Fourth "	Oats or barley—(manured.)
Fifth "	Wheat.
Sixth "	Grass—(plastered.)

The tables below are from Colman, and show some courses of rotation practiced in England.

First year—	Turnips—(manured.)
Second "	Barley.
Third "	Clover.
Fourth "	Wheat.

On a Clay Soil.

First year—	Swedes turnips and Mangel Wurtzel.
Second "	Wheat and beans, (i. e., part of land in each.)

On a Clay Soil—continued.

Third year—Clover.
Fourth " Wheat and oats.
Fifth " Vetches, rye and turnips.
Sixth " Wheat.

On a Sandy Soil.

First year—Swedes and Mangel Wurtzel.
Second " Barley.
Third " Clover.
Fourth " Oats.
Fifth " Cabbage and potatoes.
Sixth " Wheat.

On a Limestone Soil.

First year—Rye and turnips.
Second " Barley.
Third " Clover.
Fourth " Oats.
Fifth " Turnips.
Sixth " Wheat.

The table below is from Mr. J. J. Thomas' Prize Essay: it gives three courses, which are said to be well adapted to the State of New York.

First Course.

First year—Corn and roots, well manured.
Second " Wheat sown with 15 lbs. clover seed per acre.
Third " Clover one or more years, according to fertility and amount of manure at hand.

Second Course.

First year—Corn and roots with manure.
Second " Barley and Peas.
Third " Wheat, sown with clover.
Fourth " Clover, one or more years.

Third Course.

First year—Corn and roots, with manure.
Second " Barley.
Third " Wheat, sown with clover.
Fourth " Pasture.
Fifth " Meadow.
Sixth " Fallow.
Seventh " Wheat.
Eighth " Oats sown with clover.
Ninth " Pasture or meadow.

It will be evident, on a little reflection, that no definite rules can be given, and no set of tables devised which shall apply to all soils and under all circumstances. The frequency of any crop in the course of rotation, must, therefore, be determined by a consideration of the character of the soil and subsoil, the amount of manure applied, and the other crops which come in the course.*

* "In wheat farming districts and with the wheat farmer, who depends for his sales and profits solely upon wheat and wool, the following rotation with slight variation, is often adopted.

Divide all the available land into three, six or nine enclosures: let one-third be always in wheat, one-third in pasture and meadow, and one-third in summer crops well manured,—which may be followed with wheat the same fall, or may be put in barley the next spring, and followed with wheat and well clovered in all cases. The general practice is, to summer fallow the clover after spring pasturing. There should be about one sheep to the acre of all the available land; the manner of cropping the fallow is important.

Others make a four years' rotation, letting the clover lay two years,—one for pasture and one for meadow. On this system no more cattle should be kept, or butter and cheese made, or corn, oats or potatoes grown, than is required for the farm use; every thing is made subservient to the wheat crop."—L. B. Langworthy.

CHAPTER V.

STERCOLOGY.* MANURES.

All agents used by the Agriculturist to preserve or restore the productiveness of the soil, are properly called manures. All soils, after being long cultivated and subjected to the exhausting influence of continual harvests, become deficient in mineral and organic elements, which must be replaced artificially or total barrenness will ensue. Manuring is the process by which this end is accomplished,—and for it, there is *no substitute.*

If the supply be less than the crops require, the soil increases in barrenness: if it just replaces what has been removed by the crops, the fertility remains the same: if more be added than the crops require, the fertility of the land is increased.

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* A New Term—Stercology.—Mr. Editor: I wish to propose, through your paper a new term, which I think will supply a deficiency in agricultural language. We have no generic term which embraces in its signification, the science or art of enriching the soil. I therefore propose the term Stercology, which is compounded from the word *stercus*, which means manure, and *logos*, a discourse.

Although hardly general enough in its strict meaning, this word may, by a little extension, be understood to embrace everything under the head of manuring, enriching, ameliorating or amending the soil. And although words are only the signs of ideas, and technical language should not be used unnecessarily,—still a systematic division of any branch of science into parts embraced under generic heads is always convenient.

Yours, respectfully,

M. M. Rodgers."

Genesee Farmer, August, 1847.

The remains of plants, together with the excrements and carcasses of animals, if returned to the soil before decomposition, must contain all the mineral, organic and gaseous elements, which the plants derived from the soil or the atmosphere. These must pass through the different processes of decomposition, before they assume their original gaseous and earthy forms, and become again available for the food of plants.

The whole science of manuring consists in supplying to the soil, those indispensible elements which have become exhausted. The richest manure may be applied to a failing soil, and if it lacks a particular element which the crops require, and which the soil does not contain, the soil grows barren notwithstanding the manuring. Farm-yard manure, probably contains the greatest number of elements necessary to fertility; but particular plants require special manures.

Manures operate beneficially on the soil in several ways. 1. By serving directly in some instances as the food of plants. 2. By causing chemical changes in the soil, by which other substances are prepared to be taken up as nutriment by their roots. 3. By neutralizing noxious substances in the soil which prevent the growth of vegetation. The operation of lime on a cold, sour, peat soil, or one which abounds in sulphate of iron, is an example of this principle. 4. Manures change, according to their bulk and texture, the mechanical properties of soils. 5. They may change more or less, according to their various properties, the physico chemical character of a soil, in relation to light, heat, air and water. Sand, used upon a clay soil, for the purpose of rendering it more loose and friable, would be as properly a manure, as farm yard, or any other variety. Clay used to ameliorate a sandy soil, is also in effect a manure.

Manures have been classified in various ways, according to their supposed operation and nature. The most simple and convenient division, and one which is usually adopted at present, is that which arranges all of them into three classes, viz: *animal, vegetable* and *mineral manures.* The first class includes all substances of animal origin: the second includes all those of vegetable origin; and the third, all those derived directly from the mineral kingdom.

ANIMAL MANURES.*

Animal substances are better fertilizers than those of vegetable origin, on account of their chemical constitution and the facility with which they decompose: they furnish more manure in proportion to their bulk, and act more promptly and rapidly. The properties and value of these substances are given mostly on the authority of Johnston and Boussingault.

The *flesh* of animals, after and during its decomposition, is a rich and active manure: the *lean flesh* acts more energetically than the *fat.*

Blood is similar in its properties to lean flesh; it is sometimes applied as a top dressing in the form of dried powder, and sometimes mixed with other matters, to form composts. The scraps of *skin* among the refuse of curriers' shops are also used as manure.

Wool, hair, horns and *hoofs* found in large quantities among the refuse of various manufactories, contain large proportions of carbon and nitrogen, as do most animal substances, and are therefore highly concentrated manures. The refuse of fisheries, soap and candle factories, slaughter houses, kitchens, sugar manufactories, &c., all contain matters rich in those elements which characterize good fertilizers.

Animal charcoal, which is to be obtained in considerable quantities at sugar refiners' shops, in a state of mixture with blood and lime, is a manure of considerable value.

Bones are valuable on account of both the organic and mineral matters which they contain. The bones of different

* **See tables at the end of the chapter.**

animals differ somewhat in composition: *phosphate of lime* constitutes the largest proportion of the matter of dry bones; the amount is from forty to sixty per cent. of their weight. Eight pounds of bone dust are equal in phosphates to 1000 pounds of hay or wheat straw.

The value of bones is not dependent alone on the phosphates, but partly upon the gelatine and other organic matters which enter into their composition: these latter operate in the same way as the other organic tissues of animals. Bones are prepared for manure by boiling, by maceration in sulphuric acid and water, and by grinding; the last of which methods is thought on all accounts to be preferable. In soils deficient in phosphates, bones are of great value; and from the comparatively small quantity of phosphates which most crops require, the effect of a large manuring with bone dust is manifest upon the land for many years: "260 pounds of bone dust, (less than six bushels,) are sufficient to supply all the phosphates contained in the crops which are reaped from an acre during an entire fourshift rotation of turnips, barley, clover and wheat. Some lands remember a single dressing for fifteen or twenty years." (Johnston.)

The prolonged effect of bones is due to the organic as well as mineral matters. Bones should not be ground too fine: they are particularly applicable to turnip crops and pasture lands: the milk of cows contains about half a pound of phosphates to every ten gallons; hence the necessity of these salts in the soil of pastures. Animal tissues, when used as manures, ought to be well covered with earth, or ploughed under, in order to facilitate their decomposition, and at the same time prevent the escape of the gases formed during this process.

Solid excrements of animals.—Night soil, or human ordure, is a highly valuable fertilizer. It is best prepared for use by mixture with powdered charcoal, half burnt peat, or scil which is rich in vegetable matter: quick lime has been used for the same purpose; but, although it destroys the odor, it dissipates at the same time a large portion of its ammonia. During the decomposition of night soil, an evolution of carbonic acid, ammonia, sulphuretted and phosphuretted hydrogen takes place. After the escape of these gases, the odor ceases, and the remainder, when dried, constitutes what is sold in large eities under the name of *poudrette.* The odor of recent night soil may be destroyed, and the volatile elements retained, by adding to it gypsum or dilute sulphuric acid. This manure is used in the form of compost, and as a top dressing in the form of poudrette.

The *excrements of horned cattle* are more valuable and enduring in their operation than those of the horse and sheep. It ferments more slowly on account of its smaller quantity of nitrogen; hence it retains its virtue longer, and produces a more lasting effect on the soil. It is colder in its nature than that of the horse, which is owing partly to the amount of water it contains, and partly to its peculiar constitution.

The *excrements of the horse* abound more in nitrogen compounds than those of cattle. Even where both are fed upon the same food, those of the horse are more valuable than those of the cow. It begins to heat and ferment in a short time, and in two or three weeks, according to Johnston, loses nearly half its original weight. On account of this rapid fermentation and the consequent loss of volatile matters, it should be mixed as soon as possible with charcoal, peat, sawdust, or earth rich in vegetable matters, or be sprinkled with gypsum or dilute sulphuric acid. For the same reason, this kind of manure ought, contrary to popular opinion, to be spread upon and ploughed into the soil before any signs of fermentation take place; unless it is mixed with some other matters to form composts. Erom its tendency to ferment and develop heat, it is admirably adapted to enter into all composts. An additional quantity of water prevents too rapid fermentation and preserves the virtues of this manure to a considerable extent.

The *excrements of the hog* are said to be a rich manure; but they have a strong and unpleasant odor, and often impart a rank taste to the crops upon which they are used: for this reason it has been advised not to use them on crops, particularly of roots, which are designed for food. They are colder and less inclined to ferment than those of the cow, and should be combined with other manures or made into composts.

The *excrements of sheep* form a richer and more fermentable manure than those of the cow: they are said to be most beneficial on soils which contain much vegetable matter, which absorbs the volatile matters which would otherwise pass off during fermentation.

The value of all animal manures depends much upon circumstances, viz: the food upon which the animal is fed; the age and condition of the animal; the amount of labor he performs; the length of time and manner in which the manure is kept. Since, then, their value is affected by so many conditions, it is evident that no general conclusions can be drawn, which shall not be liable to exceptions; and no set of analyses can furnish tables which shall in all cases agree. The following tables may be relied upon as being as nearly correct as can be obtained, and sufficiently so for all practical purposes.

Excrements of birds.—These are among the most powerful fertilizers. The excrement of pigeons is said to be particularly valuable to flax crops, for which it is held in high esteem in some parts of Europe. This, like most other manures, loses much of its value by being allowed to ferment without the admixture of some other matters to retain its volatile elements. The principal value of this, as well as the excrements of all birds, which have been analyzed and used as manures, is dependent mainly on the large proportions of ammonia and phosphates which they contain. The excrements of hens, geese, turkeys and ducks, are of less value than those of the pigeon.

Guano is the excrements of sea fowls, and is an earthy substance of a grayish brown color: it is mostly found in Africa and South America. It is found on the islands and coasts of those countries, in latitudes where the weather is so dry that decomposition has proceeded slowly, and it has consequently accumulated in large quantities. Guano is said to be efficacious as a manure, applied to almost any crop: it is, however, according to Johnston, more advantageous to root crops than to grain or grass crops. It is conveniently applied as a top dressing, mixed with gypsum, wood ashes or powdered charcoal. Two or three hundred pounds to an acre is sufficient for a single dressing.

The *urine* of men and animals is the most valuable and the most neglected of all manures. That of the cow and hog is said to be more valuable, because it contains more solid soluble matter than that of any other domestic animal. The efficacy of urine as a manure is due to the large quantity of urea, ammonia and phosphates, and consequently of nitrogen, which it contains. Recent urine generally exerts an unfavorable influence on growing vegetation; it is most beneficially applied after fermentation has fairly commenced, and before it reaches the final stage of the process. (Johnston.)

Decomposition is attended with a diminution of urea, and an increase of ammonia. It is important that the urine collected should be fermented in tightly covered cisterns to prevent the escape of volatile matters: it has been proposed to add gypsum, sulphate of iron, or sulphuric acid, to the fermenting urine, in order to fix the ammonia; the mixture of vegetable mold with it has been also recommended as equally effective and more economical. The loss of manure in waste urine in densely populated countries and large cities, is immense, as is shown by the following calculation.

[If we allow the quantity of urine voided by each indvidual to be 600 pounds yearly, the city of Rochester, which contains 30,000 inhabitants, would furnish yearly 1,200,000 pounds, or 540 tons. This, estimated at the price of guano would be worth $21,600. Now if we estimate the number of horses and cows of the city to 500 of each, and that each animal voids as much urine as two persons, the amount would be 80,000 pounds, or 40 tons, which would be worth $1,600. Here then is a loss, if we reckon guano at $40 per ton of $23,200: or of manure enough to produce, in addition to the ordinary crop, over 16,000 bushels of wheat in a single year. These calculations may not be correct, but they approximate this point sufficiently for our purpose.]

VEGETABLE MANURES.

Organic vegetable matters in various conditions, constitute the largest part of manure in use. The form in which they are prepared and applied has an important influence on their fertilizing effect. The principal difference between dry and green vegetable matter is, that the latter decomposes more rapidly and therefore acts more promptly. Unripe plants furnish a more valuable manure than ripe ones.

Straw and *chaff*, when ploughed into the soil dry, are slow in decomposing, and act more slowly than when previously fermented. The question of applying straw without previous decomposition, is, in practice, only a question of time. It is doubtless true that it furnishes about the same amount of manure in both cases; but in the one case it has a more speedy and powerful, and in the other a more prolonged effect.

Saw dust, is a cheap, and on some accounts a valuable manure: it ferments slowly in the soil, and cannot, therefore, be much relied upon the first year or two. It is beneficial in absorbing gases and liquid manures, and its effect is felt gradually by the soil as decomposition proceeds: it is also beneficial to stiff clay land by rendering it more loose and light.

Dry leaves and *decayed wood*, operate as manures in a manner similar to saw dust; they are however better fitted by decomposition in compost heaps.

Oil cakes, from cotton and linseed exhausted of their oils, are valuable as fertilizers; but their value for fattening animals perhaps exceeds that as a manure, and may prevent their direct use for this purpose.

Peat, is used with benefit on soils which are deficient in organic matters: it decomposes slowly, especially if sour or applied alone to a wet soil containing little lime. Its action, when properly decomposed and prepared, is the same as that of other vegetable matters: it usually contains more or less mineral and gaseous matters, which have their own peculiar operation; but these are not to be considered as affecting the vegetable character of peat as a manure. On account of the slowness with which it decays, it should be mixed with lime, gypsum, wood ashes, or some vegetable matter which decomposes rapidly, such as farm-yard manure: swamp muck and humus are similar in properties to peat.

Tanners' bark, is used as a manure, but is liable to the same objection as peat in respect to its slow decay: it is best brought into a state of fermentation by mixture with lime and farm-yard manure in composts.

Soot, is a complicated substance, as will be seen by reference to the table: it contains many things necessary to vegetation, and is a manure of some value; but experiment has not yet determined its precise character and operation.

Charcoal, on account of its power of absorbing gases and destroying offensive odors, is a valuable addition to the soil: its operation is not so direct as that of some other manures; that is, it is not so useful on account of any element which it furnishes to plants, as by the intermediate office which it performs of absorbing and retaining in the soil those volatile matters which plants require, and which would otherwise escape and be lost. It is beneficial as a top dressing, and as an ingredient in composts: it evolves carbonic acid in its decomposition, and is in this way directly useful to plants. Its powerful antiseptic properties render it very beneficial to young and tender plants; by keeping the soil free of putrefying substances which would otherwise destroy their spongioles and prevent their growth.

Farm-yard manure. The manner and state in which farm-yard manure should be applied, has been a subject of much experiment and controversy. The conclusions of Johnston in relation to this subject, appear rational and satisfactory. This kind of manure is made up of the solid and liquid excrements of animals together with straw and hay, some of which are in a state of decomposition, and the remainder fresh and unchanged. The question as to which condition these manures should be used in, must depend upon circumstances. If the object is to furnish the greatest amount of organic matter to the soil, the sooner the manure is applied after it is made, the better this object is accomplished. On compact clays, the mixture of straw and coarse manure is beneficial, as it renders them looser and lighter, while the products of decomposition are more completely retained in the soil than they would be in a loose one. But coarse manures render loose soils more loose, and lose more of their elements in decomposing: for these reasons, compact fermented manures are preferable in such soils. For manuring crops which grow rapidly and attain maturity in a short time, well fermented manures and fine composts are felt more immediately and powerfully than recent ones. Such crops as turnips, buckwheat, clover, and many garden vegetables, might nearly attain maturity before decomposition would be sufficiently advanced in new and coarse manures to render them beneficial. When it is desired to force and quicken the growth of a crop, a well fermented, or fine heating manure should be used; such as rich compost, bone dust, or the excrements of the horse and sheep.

Top dressing for pastures, meadows and turnip crops, should usually be of the same kind as these just named. But farm-yard manure is not subject to any special law, but is to be used according to its quality and condition, and adapted to circumstances. Vegetable substances are all similar in their nature and operation, and are modified by conditions and circumstances. They are all subject to the same laws, and their relative value depends on their constitution and adaptation to each particular case.

GREEN MANURES.

By green manures, is understood those plants which are grown for the purpose of being ploughed in and mixed with the soil before being harvested or used as food for animals. This plan of manuring is by no means of recent origin; it was known and practiced among the Romans. The plants most in use for this purpose in the United States are red clover, buckwheat and grass in the form of green sward. Several other plants are used in Europe, viz., rape, lupine, vetches, rye, turnip, carrot and beet tops, borage, spurry, sea weeds and fresh water plants.

The advantages of green manures, according to Johnston, are,—1. They undergo decomposition sooner than dry vegetable matter, and consequently become sooner available for the food of succeeding crops. 2. The nitrogen and carbon which they contain, if allowed to decay in the open air, are lost; while if the plants had been buried, before decay, these gases would have been mostly retained in the soil for the use of succeeding crops. 3. By ploughing in a crop of plants, the organic matter is more equally distributed through the soil than could be done by any other means. 4. Green manures are available where other manures are scarce, and in soils deficient in organic matter. 5. The plants used as green manures, bring up towards the surface by their roots, matters which had sunk into the soil too deep to be of much service. 6. It restores to the soil all it took from it, in a more soluble and available condition; and in addition to this, those gases also which the plants extracted from the air during growth. 7. A green crop yields more manure than the same crop could do in any other form. 8. A grain crop is greater on the same field when green, than when fermented manures are used. The best plants for green manures are those which grow the fastest, produce the most vegetable matter, and with the smallest expense.

Sufficient seed should be sown, that the plants may cover the ground completely; the crop should be ploughed in before the time of full blowing, because the flowers give off nitrogen, which is wasted in the air. Agriculturists agree that a second and third crop of green plants still continue to improve the soil; but there must be a limit, beyond which this practice cannot be carried with benefit and profit. Green manuring might perhaps secure a field against barrenness for an indefinite period of time, providing nothing was taken off: but if a crop was occasionally carried away, in must of course be impoverished to the amount of what is taken off in mineral matters. It is probably true that lands in a state of nature, which are covered with forest trees or other vegetation, never become barren.

The soil may in time become deficient in a particular mineral element which the incumbent plants require; but when these die out, others immediately spring up by a natural rotation, and, requiring elements slightly different from the first, grow as luxuriantly as they did. Thus one race of plants succeeds another, each in turn exhausting the soil of certain elements, and leaving it richer in others. The question may arise, What becomes of the mineral elements which are lost, if nothing is taken off the soil, since they do not escape into the air? The probability is, they sink down deeper and deeper into the soil in the form of soluble salts, until beyond the reach of the roots of plants.

IMPROVEMENT OF THE SOIL BY PASTURE.

Pasture may be either temporary or permanent. *Temporary pasture* consists in laying down a field to pasture for one, two or three years, or more. The soil is benefitted by pasture in several different ways. The roots of the grass which remain furnish a large amount of organic matter, which, to a soil poor in this constituent, is of great benefit. Land which lies several years will be more benefitted than when it lies but a single year; but the first year enriches it more than any succeeding one. The result to the land will be nearly the same, whether the grass be mown or eaten off by the stock. "That farming is the most economical, where the land will admit of it, which permits the clover or grass to occupy the land for a single year only."

Permanent pasture consists in the suspension of grain crops, and the occupation of the land by grass or clover, for an indefinite period of time. Besides the benefit which the soil derives from the organic matters left in it, some of its mineral constituents are, by the action of air, moisture, and the roots of the grass, brought into a more soluble state to be used by succeeding crops. Another advantage of pasture, especially on stiff clay soil, is that it renders it more loose and friable. On dry, sandy soils, pasture is beneficial, by retaining the moisture longer, and also the dry organic matters and fine sand upon the surface, which would otherwise be blown away by the winds. Insects perform a part in improving pasture lands, which is by no means insignificant.

They subsist upon the organic matters of the soil, which they bring into a minute state of division and deposit on the surface as they ascend by night through their holes. They furnish also, considerable organic matter, which is rich in nitrogen, by the death and decay of their own bodies. Thus these earth worms and insects, in the lapse of a few years, furnish a vast amount of the richest manure without the smallest expense. The time which land may lay in pasture and still increase in richness, must have a limit,—and this depends upon the quality of the soil and the kinds of grass which occupy it.

The soil will require an occasional top dressing, or the pasture will deteriorate: on account of the exhaustion of certain elements in the soil, grasses, as well as forest trees and other plants, tend to a natural rotation; one species, after flourishing a few years, begins to decline and finally dies out, and is replaced by another, and this, in time by another,—and so on, indefinitely. All pasture lands whatever, which are arable, can, after a series of years, be subjected to grain crops; and this in most cases would doubtless be expedient. This, however, must be determined in each particular case, by an appreciation of all the circumstances and conditions.

CHAPTER VI.

MINERAL MANURES.

Mineral manures are divided, for the sake of convenience, into saline and earthy; the former including pure salts whose composition is exactly known, such as common salt and carbonate of soda; and the latter including the various earthy matters used to ameliorate the soil, such as lime, wood ashes, and marl. The mineral manures are all supposed to have a specific mode of action, which is peculiar to each respectively: the theory of their action, however, as fertilizers, cannot, for want of space, except in a few cases, be detailed. But few, comparatively, of the known mineral fertilizers are in common use, and those only will be described.

SALINE MANURES.

Carbonate of soda.—This salt, according to Johnston, is beneficial on lands abounding in sulphate of iron, or overgrown with mosses and other noxious vegetation; and also as a top dressing to fields of young grain, and wherever wood ashes would be useful. It is said to be peculiarly beneficial to the strawberry. From forty to sixty pounds may be applied to an acre, either in powder mixed with other manure, or in solution.

Sulphate of soda, or *Glauber's salt,* has been used with much benefit on fruit trees, rye, beans, beets, and some other crops. The quantity used should be at least one hundred pounds per acre, either in solution or in powder just before a rain. [It must not be inferred, that this, or any other manure, because it is recommended for a particular species of plants, is not therefore adapted to the growth of others; but those only are mentioned, upon which they have been tried sufficiently to warrant a conclusion as to their efficacy.]

Sulphate of magnesia, or *epsom salts*, is said to be useful to young crops of wheat, clover, peas and beans: one or two hundred pounds to an acre should be used.

Sulphate of lime, or *gypsum*.—This salt of lime, usually called "plaster," has been long known and much employed as a fertilizer on almost all crops and soils. It requires much water for its solution. The beneficial operation of gypsum is supposed to depend upon several circumstances. This, like all the sulphates, furnishes sulphur, which is important in the nutrition of plants, especially those of the liguminous order. Gypsum prevents the escape of ammonia which is deposited in the soil by rain, and evolved by the decomposition of animal and vegetable matters. In soils deficient in lime, it supplies this element in an available state for their nutrition. It has been thought to operate most beneficially on red clover and Indian corn.

Nitrate of soda is on some accounts a good fertilizer; it has not come into general use, and is not as well understood in its relations to soils and to plants as it should be. Several results are theoretically attributed by Johnston to the action of the nitrates on vegetation. 1. They give a dark green color to the leaves. 2. They hasten and sometimes prolong the growth of vegetation. 3. They increase both the straw and the grain of the cereals. 4. They impart a saline taste to hay and straw, which causes cattle to eat them with more avidity. 5. Grain which has been manured with the nitrates yields more bran and less flour than those manured with other salts The nitrates increase the oat crop; they should not, however, be used for any crop on land which is already disposed to produce too much straw. They are exceedingly soluble, and are for this reason not so beneficial on loose, light soils, because more easily washed away than on close, compact soils: for the same reason they produce little effect after the first year. They furnish a large amount of nitrogen, and are most beneficial to poor soils which are deficient in organic matters.

Chloride of sodium, or *common salt,* has been used with various results as a fertilizer. Plants require for their growth both of the elements of common salt, viz,—chlorine and soda; and in soils which are deficient in one or both of these elements, there can be no doubt as to its efficacy; but in a soil which contains them in sufficient quantity in a soluble state, it cannot be expected that this salt will be of any service. It is most likely to prove beneficial on lands lying remote from the sea, and which, consequently, would be more apt to require it. This salt is of more benefit to green crops than cereals; and also to hasten and increase the growth of the herbage of plants than the seeds.

The *chlorides of lime* and *magnesia* contained among the refuse of chemical manufactories, are also used as manures with good effects. The chlorides are destructive to both animal and vegetable life, when used in large quantity; they have consequently been used to destroy weeds, worms and insects in the soil.

The *silicate of potash and soda,* and the various *salts of ammonia,* are, without question, powerful fertilizers, particularly on the grasses; but they are not in general use, on account of their high price, as well as doubtful reputation among those practical men who have not tested them.

EARTHY MANURES.

Wood ashes. The ashes of wood and all other vegetable matter, contain various proportions of several different salts, all of which are necessary to the growth of plants. The following table presents an analysis of the ashes of the red beech and oak, by Sprengel.

	Red Beech.	Oak.
Silica,	5.52	26.95
Alumina,	2.33	
Oxide of Iron,	3.77	8.14
Oxide of Manganese,	3.85	
Lime,	25.00	17.38
Magnesia,	5.00	1.44
Potash,	22.11	16.20
Soda,	3.32	6.73
Sulphuric Acid,	7.64	3.36
Phosphoric Acid,	5.62	1.92
Chlorine,	1.84	2.41
Carbonic Acid,	14.00	15.47
	100.	100.

It will be seen by the table, that one kind of ash is richer in one element, and another in some other element: the value of each must be estimated accordingly. The ashes of the oak and beech, both contain more lime than they do potash, and would therefore be as efficacious on a soil deficient in lime, as on one deficient in potash. We see, then, that, contrary to popular opinion, the utility of this manure does not depend solely upon the action of potash, but on several other elements also.

Ashes, as a general rule, are used with benefit on the grasses, luguminous and Indian corn crops. They may be mixed with an equal quantity of gypsum or bone dust, and applied to the amount of ten to thirty bushels to an acre; or, if the ashes have been leached, fifty, sixty, or a hundred bushels may be used to an acre. According to Johnston, only about one fifteenth part of the weight of ashes are immediately soluble; their effects are therefore more permanent than those of any of the soluble saline manures, being felt by the land for more than ten years.

The following mixture is said to be nearly equal in efficacy for a year or two, to one ton of wood ashes.

Crude potash,	60	pounds.
Crystalized carbonate of soda,	60	"
Sulphate of soda,	20	"
Common salt,	20	"
	160	

Leached ashes are nearly destitute of potash, and cannot, of course, supply this substance to vegetation; they are said, however, to be of service to oat crops in particular, and are beneficial to clay soils. The ashes of *coal, peat, turf, straw* and *cane* are also valuable as fertilizers, according to their constitution and the crops to which they are applied.

Crushed or pulverized rocks of various kinds could be used with the same benefit and in the same cases, according to their elementary composition, as other mineral manures: *crushed granite* would furnish a considerhble amount of potash; it is easily ground after being heated to a red heat. *Crushed trap* contains much lime, and is a good manure: *crushed lavas* are also valuable on most soils.

Marl. The composition and other chemical characters of marl have been described: it consists of lime, clay, and often sand, shells, and other matters. The object and effect of marling are similar to those of liming land. Marl should be used according to its constitution; clay marl should usually be put on sandy soils, and lime or sandy marl on clay soils. The best time for laying on marl is at the end of autumn, so that it may be pulverized by frosts during the winter. Boussingault says, land which contains ten per cent. of carbonate of lime can dispense with marl.

The effect of marl is not unlimited, but, like lime, requires to be repeated once in 10 or 12 years. With regard to the quantity of marl which should be used to an acre, we must be governed by the same rational considerations as the use of all other manures; viz., it should be applied where it is required, and in quantity equal to the demand of the soil. The opinions of practical men vary greatly on this subject: according to Johnston, ten or fifteen, to one hundred and twenty tons are used to an acre; while Boussingault says, "allowing the broadest margin, and judging from the composition of the ashes of the plants of ordinary crops, we can see that the quantity of three and a half bushels of marl of the usual composition per acre, which is assumed as the average quantity to be laid on, is vastly more than can be absolutely necessary."

This discrepancy has arisen partly from the extravagant notions about the virtues of marl, and partly from the nature of the marl and the soils to which it has been applied by different experimenters.

Chalk is much used as a fertilizer in some parts of Europe where it is cheap and abundant; but, from its scarcity and price, it can never be expedient to use it in this country while we have such an abundance of lime in various other forms. When used, it is subject to nearly the same laws as lime and marl. Its composition varies; some specimens contain more phosphate of lime, magnesia and silicates, than others. Ehrenberg has made the remarkable discovery, that chalk to a considerable extent, is composed of the shells or skeletons of marine microscopic animals.

Lime. The chemical and physical properties of lime have already been described, and it remains for us to examine briefly the principles of its adaptation to the soil as a fertilizer. Much discussion has been had, and many long essays written on this subject; but no chemist claims for this substance any exception to general chemical laws, or attributes to it any action more specific than that of any other manure. There is no doubt that all our present knowledge of lime as a manure, can be expressed in a few known and plain principles: we do not assume that all is known about lime that may be known at some future time, but that the facts can be much more briefly and perhaps more clearly set forth than is done by most writers on agriculture.

Lime is perhaps the most important mineral used as a manure. When applied to a soil entirely destitute of lime, the quantity will necessarily be larger than at subsequent periods.

The quantity used must be determined, as in all other cases, by circumstances. No general rule can be given for its use, but each one must judge from the facts in the case and proceed accordingly. Johnston says, "if we suppose one per cent. to be necessary, then upwards of 300 bushels of slaked lime must be mixed with a soil six inches in depth, to impart to an acre this proportion." On wet, peaty, marshy, or clay soils, more lime will be necessary than on dry, sandy and loose soils: on soils which contain much organic matters also, more may be used than on those nearly destitute of them. It is considered better economy to apply lime in smaller quantities and at shorter intervals, than to use it in large quantities at more distant periods.

Caustic lime should be applied to marshy and clay soils immediately after slaking: when allowed to slake in the open air spontaneously, without the use of water, it is more mild, and better adapted to grass lands and young crops; but when applied to naked fallow and mixed with the soil, it may be used in either state. Burned lime is well adapted to the compost form of manures. As quick lime dissipates the ammonia of fermenting manures in the soil, it ought not to be applied at the same time, nor to come in immediate contact with them: it is best applied usually in the fall, or as long as possible before the next crop is sown.

These principles apply only to caustic lime: unburned lime, marl, gypsum, chalk, and composts containing lime, may be applied at any time. Lime, in order that it may produce its full effect and most lasting benefit, should be kept near the surface. This may be done by sub-soil ploughing, by which the lime is thrown up to the surface; and also by sowing deep rooted crops, which will reach it after it has sunk too deep to benefit others of shorter roots. The amount of lime in the soil gradually diminishes from several causes, when it is not occasionally replenished: it is removed to a small extent with the annual harvests, and by assuming new forms by chemical action; a portion is also carried away in solution with the water which falls by rain and filters through both the surface and subsoil.

The beneficial effects of lime, although more permanent, are not felt as soon as those of some other mineral manures: it is of little service on soils deficient in organic matter. The length of time which lime shows its effects upon the crops and soil, is, according to circumstances, from ten to thirty years. Its use is sometimes attended by unfavorable results when not judiciously used: light, loose soils are rendered too loose; and the growth of certain noxious weeds favored by its presence: an over-dose destroys too much organic matter, hardens certain soils, and injures the spongioles of young plants. It is said to operate injuriously upon flax, by causing tenderness of its cortical fibre.

These remarks on the use of lime as a manure, are condensed from Johnston, who has given perhaps the best treatise on lime extant. As the subject is both important and interesting, it may be well to recapitulate briefly.

Recapitulation.

1. Lime increases the fertility of soils deficient in this element.

2. It causes the soil to produce grain which yields more flour and less bran, and improves the quality of all other crops.

3. It increases the effect of other manures by hastening decomposition.

4. It destroys noxious insects and worms.

5. It destroys noxious weeds and mosses, and gives rise to sweet grasses and herbage.

6. It prevents smut in wheat and other crops.

7. It hastens the maturity of the crop.

8. It neutralizes the acidity of sour soils and renders them productive.

9. It makes cold wet soils dryer and warmer.

10. It renders tight stiff clays loose and friable

11. It destroys noxious gases and promotes health.

12. It stiffens loose sandy soils.

13. It brings inert organic matters into a state of fermentation.

14. It causes the evolution of carbonic acid.

15. It serves directly as the food of plants.

16. It causes the formation of several salts in the soil.

COMPOSTS.

It was formerly supposed, that great advantage was derived from the combination of several different substances together, and forming what are called *composts.* The recipes for these compounds are numerous, and go to prove that the discovery of a good compost requires but little scientific or practical skill. When a compost heap is made up of several materials which are all separately good manures, it follows of necessity that the resulting compound must be a good fertilizer. But it is impossible to supply any more in this way than if these several ingredients were applied to the soil separately. And a little knowledge of chemistry will show that by this means, no new elements can be generated. Neither can any new property be developed which could not be done by their separate action. We see that whenever a substance which has little or no fertilizing power, is in this way manufactured into a good manure, it is done at the expense of some powerful fertilizer which is diluted by the mixture, and consequently loses just as much of its efficacy as the other gains. Thus, although this process serves to dilute and extend manures which are too powerful or too expensive, it absolutely supplies none.

Now, although it is evident that this method does not augment in the slightest degree, our quantity of available manure,—yet it has several advantages. Caustic lime and wood ashes are sometimes too strong for young and tender vegetation; and when this is the case, the object of their use is much better attained by mixing and diffusing them through some other substance, such as saw-dust, sand, barn manure or humus, or allowing them to lie in a heap together with any vegetable matters, such as leaves, straw, chaff, rotten wood or turf; or with animal matters; until decomposition is completed.

Another advantage is, that a manure which is valuable and scarce, as guano, poudrette, and some chemical salts, may be extended by mixture so as to be applied to a much larger space than would be practicable if used singly. Thirdly, this mode enables the agriculturist to spread his manure on the soil more even and uniformly. And lastly, by making compost we are enabled to hasten the final decay of animal and vegetable matters, so as to gain considerable time. By mixing quicklime with barn manure, straw, leaves, &c., decomposition goes on more rapidly, and these substances are transformed to available manures in a comparatively short space of time. But much discretion is necessary in this respect, otherwise some valuable elements are wasted; the object is to fix and retain the volatile elements—and not to dissipate them. A great objection to composts is, the amount of labor required in making, turning, and transporting them to the fields.

No definite formula can with any propriety be given for making composts, as the agriculturist must determine for himself in each particular case, as to what elements his fields most require, and also his time and the resources at his command. With these considerations, and an adequate knowledge of his business, he will be able to make a more judicious disposition of his manures than by the aid of any prescribed rules which can be laid down in books.

CHAPTER VII.

TABLE OF THE COMPARATIVE VALUE OF MANURES,

FROM ANALYSES BY MESSRS. PAYEN AND BOUSSINGAULT.

Kind of Manure.	Water pr 100 lbs.	Nitrogen in 100 of matter.		Qual'y according to state.		Equival'nt accord. do.	
		Dry.	Wet.	Dry.	Wet.	Dry.	Wet
Farm-yard manure,	79.3	1.95	0.41	100	100	100	100
Water from do.	99.6	1.54	0.06	78	2	127	68
Wheat straw,	19.3	0.30	0.24	15	60	650	167
Rye straw,	12.2	0.20	0.17	10	42.5	975	235
Oat straw,	21.0	0.36	0.28	18	70	542	143
Barley straw,	11.0	0.26	0.23	13	57.5	750	174
Wheat chaff,	7.6	0.94	0.85	48	212.5	207	47
Pea straw,	8.5	1.95	1.79	100	447.5	100	22
Buckwheat straw,	11.6	0.54	0.48	27	120	301	83
Dried potato tops,	12.9	0.43	0.37	22	92.5	453	108
Oak leaves,	25.0	1.57	1.18	80	293	125	34
Beech leaves,	39.3	1.91	1.18	78	294	102	34
Burnt sea weed,	3.8	0.40	0.38	20	95	488	105
Oyster shells,	17.9	0.40	0.32	20	80	488	125
Sea-side marl,	1.0	0.52	0.51	26.5	128	377	78
Oak saw-dust,	26.0	0.72	0.54	36	135	256	74
Oil cake of linseed,	13.4	6.00	5.20	307	1300	33	8
Refuse of cider apples,	6.4	0.63	0.59	32	147	309	68
Cow's ordure,	85.9	2.30	0.32	117	80	84	125
Cow's urine,	88.3	3.80	0.44	194	110	51	91
Excrements of horse,	75.3	2.21	0.55	113	137.5	88	73
Urine of do.	79.1	12.50	2.61	641	652.5	15.5	15.3
Excrements of pig,	8.14	3.37	0.63	172	157.5	58	63

Kind of Manure.	Water pr 100 lbs.	Nitrogen in 100 of matter.		Qual'y according to state.		Equival'nt accord. do.	
		Dry.	Wet.	Dry.	Wet.	Dry.	Wet
Excrements of sheep,	63.0	2.99	1.11	153	277.5	65	36
Do. of goat,	46.0	3.93	2.16	201	540	50	18.5
Poudrette,	12.5	4.40	3.85	225	962	44	10.3
Urine of public vats,	9.6	17.56	16.83	900	4213	11	2.3
Excrements of pigeons,	9.6	9.02	8.30	462	2075	21.5	5.0
Guano,	19.6	6.20	5.00	323	1247	31.5	80
Dried muscular flesh,	8.5	14.25	13.04	730	3260	13.5	3
Liquid blood,	81.0		2.95	795	736		13.3
Fresh bones,	30.0		6.22		1554		6.5
Dregs of glue,	33.6	5.63	3.73	288.4	933.5	35	11
Sugar refiners' scum,	67.0	1.58	0.54	81	134	127	75
Horn shavings,	9.0	15.78	14.36	809	3590	12.3	3.0
Wood soot,	5.6	1.31	1.15	67	287.5	149	35

TABLES OF ANALYSIS.

Tables showing the relative proportions of inorganic compounds in the ashes of several cultivated plants.

The tables are taken from Prof. Johnston's Agricultural Chemistry,—and are supposed to be nearly correct: analysis of different varieties and qualities of the same plants, vary slightly; but still, for all practical purposes, the tables here given are sufficiently accurate, being probably as near the real constitution of them, as it is possible to obtain.

ASH OF WHEAT.

According to Sprengel's analysis, 1000 lbs. of wheat leave 11.77 lbs. of ashes,—and 1000 lbs. of straw leave 35.18 lbs. of ash, after burning.

This ash consists of

	Grain of Wheat.	Straw of Wheat.
Potash,	2.25 lbs.	0.20 lbs.
Soda,	2.40	0.29
Lime,	0.96	2.40
Magnesia,	0.90	0.32

ASH OF WHEAT—*Continued.*

	Grain of Wheat.	Straw of Wheat.
Alumina and a trace of Iron,	0.26 lbs.	0.90 lbs.
Silica,	4.00	28.70
Sulphuric acid,	0.50	0.37
Phosphoric acid,	0.40	1.70
Chlorine,	0.10	0.30
	11.77 lbs.	35.18 lbs.

ASH OF BARLEY.

100 of grain of barley leaves 23.49 lbs.—1000 lbs. of straw 52.42 of ash.

	Grain.	Straw.
Potash,	2.78	1.80
Soda,	2.90	0.48
Lime,	1.06	5.54
Magnesia,	1.80	0.76
Alumina,	0.25	1.46
Oxide of iron,	a trace	0.14
Oxide of manganese,		0.20
Silica,	11.82	38.56
Sulphuric acid,	0.59	1.18
Phosphoric acid,	2.10	1.60
Chlorine,	0.19	0.70
	23.49 lbs.	52.42 lbs.

ASH OF OATS.

1000 lbs. of the grain of oats contain 25.80 lbs.—and of straw, 57.40 lbs. of ash.

	Grain.	Straw.
Potash,	1.50	8.70
Soda,	1.32	0.02
Lime,	0.86	1.52
Magnesia,	0.67	0.22
Alumina,	0.14	0.06

ASH OF OATS—*Continued.*

	Grain.	Straw.
Oxide of iron	0.40	0.02
Oxide of manganese,		0.02
Silica,	19.76	45.88
Sulphuric acid,	0.35	0,79
Phosphoric acid,	0.70	0.12
Chlorine,	0.10	0.05
	25.80 lbs.	57.40 lbs.

ASH OF RYE.

1000 lbs. of rye straw contain 27.93 lbs., and of grain 10.40 lbs. of ash.

	Grain.	Straw.
Potash,	5.32 (Potash and Soda)	0.32
Soda,		0.11
Lime,	1.22	1.78
Magnesia,	1.78	0.12
Alumina,	0.24	0.25 (Alumina and Oxide of iron)
Oxide of iron,	0.42	
Oxide of manganese,	0.34	
Silica,	1.64	22.97
Sulphuric acid,	0.23	1.70
Phosphoric acid,	0.46	0.51
Chlorine,	0.09	0.17
	10.40 lbs.	27.93 lbs.

ANALYSIS OF PEAT BY BOUSSINGAULT.

Silica,	65.5
Alumina,	16.2
Lime,	6.0
Magnesia,	0.6
Oxide of iron,	3.7
Potash and Soda,	2.3

ANALYSIS OF PEAT, BY BOUSSINGAULT—*Continued.*

Sulphuric acid,	5.4
Chlorine,	0.3
	100.0

ANALYSIS OF COAL ASHES BY BOUSSINGAULT.

Argillaceous matter insoluble in acids,	62
Alumina,	5
Lime,	6
Magnesia,	8
Oxide of manganese,	3
Oxide and sulphuret of iron,	16
	100

ASH OF THE BEAN AND PEA.

1000 lbs. of seed and straw, dried, contain—

	Field Bean.		*Field Pea.*	
	Seed.	Straw.	Seed.	Straw.
Potash,	4.15	16.56	8.10	2.35
Soda,	8.16	0.50	7.39	
Lime,	1.65	6.24	0.58	27.30
Magnesia,	1.58	2.09	1.36	3.42
Alumina,	0.34	0.10	0.20	0.60
Oxide of iron,		0.07	0.10	0.20
Oxide of manganese,		0.05		0.07
Silica,	1.26	2.20	4.10	9.96
Sulphuric acid,	0.89	0.34	0.53	3.37
Phosphoric acid,	2.92	2.26	1.90	2.40
Chlorine,	0.41	0.80	0.38	0.04
	21.36	31.21	24.64	49.71

ASH OF THE TURNIP AND POTATO.

10,000 lbs. of the roots, stalks and leaves, when taken before drying, contain—

	Potato.		Turnip.	
	Roots.	Tops.	Roots.	Leaves.
Potash,	40.28	81.9	23.86	32.3
Soda,	23.34	00.9	10.48	22.2
Lime,	3.31	129.7	7.52	62.0
Magnesia,	3.24	17.0	2.54	05.9
Alumina,	0.50	00.4	0.36	00.3
Oxide of iron,	0.32	00.2	0.32	01.7
Oxide of manganese,				
Silica,	0.84	49.4	3.88	12.8
Sulphuric acid,	5.40	04.2	8.01	25.2
Phosphoric acid,	4.01	19.7	3.67	9.8
Chlorine,	1.60	05.0	2.39	8.7
	82,83	308.4	63,03	180.9

ASH OF THE CARROT AND PARSNEP.

	Carrot.	Parsnep.
Potash,	53.33	20.79
Soda,	9.22	7.02
Lime,	6.57	4.68
Magnesia,	3.84	2.70
Alumina,	0.39	0.24
Oxide of iron,	0.33	0.05
Oxide of manganese,	0.60	
Silica,	1.37	0.84
Sulphuric acid,	2.70	5.40
Phosphoric acid,	5.14	4.01
Chlorine,	0.70	1.60
	66.19	82.83

ASH OF GRASS AND CLOVER.

100 lbs. of dry hay and clover contain—

	Rye Grass.	Red Clover.
Potash,	8.81	19.95
Soda,	3.94	5.29

ASH OF GRASS AND CLOVER—*Continued.*

Lime,	7.34	27.80
Magnesia,	0.90	3.33
Alumina,	0.31	0.14
Oxide of iron,		
Oxide of manganese,		
Silica,	27.72	3.61
Sulphuric acid,	3.53	4.47
Phosphoric acid,	0.25	6.57
Chlorine,	0.06	3.62
	52.86	74.78

The practical inferences from these tables are,—first—the kind of soil in which each will grow best,—second—the kind of inorganic matter necessary to be supplied artificially,—third—their nutrient properties, and the *kind* of stock they are best adapted to nourish.

The following table from "Liebig's Agricultural Chemistry," shows the relative proportions of potash, lime and silica in several cultivated plants.

SILICA PLANTS.

	Salts of Potash and Soda.	Salts of Magnesia and Lime.	Silica.
Oat straw and seeds,	34.00	4.00	62.00
Wheat straw,	22.50	7.20	61.50
Barley straw and seeds,	19.00	25.70	55.30
Rye straw,	18.65	16.52	63.89
Good hay,	6.00	34.00	60.00

LIME PLANTS.

Tobacco,	24.34	67.44	8.30
Pea straw,	27.82	63.74	7.81
Potato tops,	4.20	51.40	63.40
Meadow Clover,	39.20	56.00	4.90

POTASH PLANTS—*Continued.*

Corn stalks,	72.45	6.50	18.00
Turnips,	81.60	18.40	
Beet roots,	88.00	12.00	
Potatoes,	85.81	14.19	

The following table from Johnston, shows the composition of the ashes of several grains without the straw.

	Wheat.	Oats.	Barley.	Rye.
Potash and soda,	37.72	19.12	20.70	37.21
Lime,	1.93	10.41	3.36	2.92
Magnesia,	9.60	9.98	10.05	10.13
Oxide of iron,	1.36	5.08	1.93	0.82
Oxide of manganese,	1.25	?	?	?
Phosphoric acid,	49.32	46.26	40.63	47.29
Sulphuric acid,	0.17		0.26	1.46
Silica,		3.07	21.99	0.17
	101.35	93.92	98.92	100

There appears to be some mistake in the figures of this table, as will be seen on adding up the columns; but still, for want of a more accurate one we must take this as it is, being sufficiently accurate for all practical purposes.

ASHES OF THE FÆCES OF THE HORSE: ANALYSIS OF JACKSON.

Phosphate of lime,	5.00
Carbonate of do.,	18.75
Phosphate of magnesia,	36.25
Silicic acid,	40.00
	100.

URINE OF THE HORSE: ANALYSIS OF VAUQUELIN.

Carbonate of lime,	1.1
Carbonate of soda,	.9
Hippurate of do.	2.4
Muriate of potash,	.9
Urea,	.7
Water,	44·0
	50.0

ASHES OF THE FÆCES OF THE COW: ANALYSIS OF HAIDLEN.

Phosphate of lime,	10.9
Phos. magnesia,	10.0
Phos. iron,	8.5
Carbonate of potash,	8.5
Sulphate of lime,	3.1
Silicic acid,	63.7
Loss,	2.3
	107.0

URINE OF THE COW: ANALYSIS OF BRANDE.

Muriate of potash and ammonia,	1.5
Sulphate of potash,	0.6
Carbonate of potash,	0.4
Phosphate of lime,	0.3
Urea,	0.4
Water,	96.8
	100

ASHES OF HUMAN FÆCES: ANALYSIS OF BERZELIUS.

Sulphate of lime and phosphate of lime and magnesia,	67
Sulphate of soda and potash and phos. of soda,	5
Carbonate of soda,	5
Silicic acid,	11
Carbon and loss,	12
	100

HUMAN URINE: ANALYSIS OF BERZELIUS.

Urea,	30.10
Lactic acid (?) lactate of ammonia (?) extractive animal matter,	17.14
Uric acid,	1.00
Mucus,	0.32
Sulphate of potash,	37.01
Sulphate of soda,	3.16
Phosphate of soda,	2.94

HUMAN URINE—*Continued.*

Muriate of soda,	4.45
Phosphate of ammonia,	1.65
Phosphate of magnesia and lime,	1.00
Muriate of ammonia,	1.50
Silicic acid,	0.03
Water,	933.00
	1000

GUANO: ANALYSIS OF VOLKEL.

Muriate of ammonia,	4.2
Oxalate, do.	10.6
Urate do.	9.0
Phosphate do.	6.0
Sulphate of potash,	5.5
Sulphate of soda,	3.8
Phosphate of ammonia and lime,	2.6
Phosphate of lime,	7.0
Oxalate of do.	14.3
Residue soluble in uric acid,	4.7
Loss, (water, ammonia and organized matter,)	32.3
	100

BONES OF THE OX: ANALYSIS OF BERZELIUS.

Animal matter, (gelatine,)	33.30
Soda with common salt,	1.20
Carbonate of lime,	11.30
Phosphate of do.	51.04
Fluoride of calcium, (?)	2.00
Phosphate of magnesia,	1.16
	100

COAL SOOT: ANALYSIS OF BRACONNOT.

Ulmic acid,	302.0
A reddish brown substance containing nitrogen, and yielding ammonia when heated,	200.0
Asboline,	5.0

COAL SOOT—*Continued.*

Carbonate of lime with a trace of magnesia,	146.6
Acetate of lime,	56.5
Sulphate of lime,	50.0
Acetate of magnesia,	5.3
Phosphate of lime, with a trace of iron,	15.0
Chloride of potassium,	3.6
Acetate of potash,	41.6
Acetate of ammonia,	2.0
Silica,	9.5
Charcoal powder,	38.5
Water,	125.0
	100

WOOL, HAIR, HORN: ANALYSIS OF JOHNSTON.

	Wool.	Hair.	Horn.
Carbon,	50,65	51.53	51.99
Hydrogen,	7.03	6.69	6.72
Nitrogen,	17.71	17.94	17.28
Oxygen and sulphur,	24.61	23.84	24.01
	100	100	100

DRY OX BLOOD AND MUSCULAR FLESH: ANALYSIS OF PLAYFAIR AND BOECKMAN.

	Dry Flesh.	Dry Blood.
Carbon,	51.83	51.96
Hydrogen,	7.57	7.25
Nitrogen,	15.01	15.07
Oxygen,	21.37	21.30
Ashes,	4.23	4.42
	100	100

Remark.—We have, all through the course of this treatise, adhered to the principle that nature preserves a uniformity in the execution of all her laws, and that she does nothing by accident. And whenever we find an apparent exception to this principle, it is evident that our knowledge is deficient or our conclusions erroneous.

Hence, although plants may be made to maintain a transitory and sickly existence without all the usual elements, and to absorb both by their leaves and roots, substances unnecessary and pernicious to their growth, still from the uniformity of the elements and their proportions, as shown by analysis of the plants and the soils in which they thrive best, we are compelled to conclude, that each and all of these elements, are indispensible to their *healthy growth and maturity.* And whoever *practically* disregards this principle, and hangs his hope of success on some contingent circumstance, must correct his error at his own cost.

CHAPTER VIII.

ANALYSIS OF SOILS.

The agriculturist may, by long experience and close observation of the character and productions of his lands, become acquainted with their general character and fertility,—and also what plants are best adapted to them. But it is desirable that a more accurate knowledge of the elementary constitution and the relative proportions of those elements which constitute the food of plants, should be attained.

The only direct and certain means of arriving at this result is chemical analysis. Without this process, it could only be known by a trial of various crops upon different soils, whether they were adapted to them or not: and, in order to determine the value of soils in this way, several crops and much labor might be lost in unsuccessful experiments.

Analysis of plants shows with absolute certainty what substances they have drawn from the soil and atmosphere for food; these substances vary in different plants, both in their nature and proportions: the same is also true in relation to the elementary composition of soils. No two plants and no two soils have precisely the same chemical composition. The absence of a single element in a soil may render it totally barren for a particular crop, while it may produce some others in great abundance.

A chemical difference in two soils, which might appear insignificant, would, by experiment, be found to alter entirely their relative agricultural value.

By referring to tables of the analysis of plants, and then analyzing the soil, we can see at once what plant the soil is adapted to produce. A soil containing all the organic and inorganic elements of a particular plant, may be supposed capable of producing the plant: but a soil deficient in one or more of these elements cannot be expected to yield a crop. A soil containing very little silica could not yield grass, but might still contain enough for a crop of turnips.

An exact analysis of the quality of a soil, with the quantity of each element, requires the skill of a practical chemist, and the apparatus of a laboratory: but the most important qualities of a soil may be determined by a few plain and simple experiments, which are easily made by any one, whether acquainted with chemistry or not.

The soil is made up, as before said, of various proportions of animal, vegetable, mineral, earthy and gaseous matters. As a general rule, the earthy part of the soil is estimated at from 90 to 96 per cent. The salts of these earthy matters are in small quantities. The amount of vegetable matter varies greatly in different soils: in some, as in peat and muck soils, it constitutes from one half to three fourths of their entire weight; while in sand and clay soils, it amounts to only from one to five per cent. The principal bulk of all soils, (except peat, humus and muck soils,) is sand, clay and lime; and on the proportions of these, their peculiar properties, both chemical and physical, depend. The fertility of a soil is not dependent upon any one of these, but upon the proportions and state of mechanical division of all the other necessary elements. The mixture of sand and lime with the other elements, (except the alumina,) is usually entirely mechanical: in the various kinds of clay, the silex and alumina are often chemically combined, constituting a silicate of alumina.

The first process in the analysis of a soil is to weigh a given quantity with apothecaries' scales; it should then be spread out on a piece of clean paper and subjected to a heat not sufficiently high to burn the vegetable matters which it contains, until thoroughly dried: after drying, the soil should be again accurately weighed, and the second weight subtracted from the first, when the remainder will show the amount of water lost.

To find the amount of organic matter which it contains, put the dried soil into an earthen crucible and heat it over a fire to redness, till the organic matter is burned out and the ash only remains; after cooling, it should be again weighed,—the loss by burning shows the amount of organic matter it contained, allowing a trifle for the charcoal which remains with the earthy part. If a black soil loses nothing by burning, it probably derives it color from black oxide of iron or graphite.

To detect humic acid, boil a small quantity of peat or muck in a solution of carbonate of soda, until it attains a brown color, then add muriatic acid till the solution has a distinctly sour taste, when brown flocks of humic acid will fall to the bottom.

Ulmic acid may be obtained from the same soil, after the humic acid is separated, by digesting it over a gentle heat in a solution of caustic ammonia, and then adding muriatic acid as before;—brown flocks are precipitated, which are ulmic acid.

To detect crenic and apocrenic acids, digest a quantity of soil in hot water until organic matter is dissolved out sufficient to give the water a yellow color. When this solution is evaporated to dryness, there remains a brown residue, which contains the soluble saline matters of the soil, some extractive matter, humic and ulmic acids, and the crenic and apocrenic acids: these four acids are all in combination with alumina and other bases. When this residue is dried at 220° F., the compounds of the humic and ulmic acids become insoluble, while the compounds of the crenic and apocrenic acids remain soluble, and may be separated by washing in water. (Johnston.)

To detect the presence of lime, take 100 grains of a soil and mix well with half a pint of cold water, and then add half an ounce of muriatic acid, stirring the mixture frequently: let it stand a few hours to settle, then pour off the water and fill the vessel with water to wash out the excess of acid; when the water is clear, pour it off, dry the soil and weigh it;—the loss from the first weight will show the quantity of lime sufficiently near for all practical purposes. (Gaylord.)

To determine the amount of sand, take a given quantity of soil and boil it in water till it is thoroughly incorporated with it, then pour the whole into a glass vessel and leave it till the sand subsides: the clay remains in a state of mixture with the water, which should be poured off and the sand dried and weighed. If the sand contains lime, it may be separated by muriatic acid as above directed.

The amount of clay may be very nearly ascertained by evaporating the water which was poured off of the said,—the residue will be mostly clay.

To detect the presence of oxide of iron, mix a quantity of soil with water, pour on muriatic acid and stir the mixture; let it stand a few hours and dip a piece of oak bark into the solution,—if the bark is colored brown or black, iron is present.

"To detect the presence of other salts, boil a portion of soil in water, pour off the water and evaporate it, when the salts may be obtained in crystals.

If the salt is a nitrate, it has a cool pungent taste, and ignites when thrown on coals of fire.

If it be common salt, (muriate of soda,) it burns with a crackling noise, and is also known by its taste.

Sulphate of soda puffs up by heat, gives off a watery vapor and leaves a dry white mass."

These directions are sufficient to enable any one to make a rough analysis of a soil, which, although not strictly correct, may be of much service in determining the general character of a farm, when a rigid and exact analysis cannot be obtained. We give below two tables,—one showing the composition of a barren, and the other of a fertile soil. Taking the mineral constituents of plants as a basis on which to predicate our reasoning in relation to the productive value of soils, we see at once, that one of these tables shows a soil rich in all the elements of fertility, while the other exhibits one almost irredeemably barren.

ANALYSIS OF A NEW SOIL ON THE BANKS OF THE OHIO RIVER, POSSESSING GREAT FERTILITY.

Quartz sand and silicates,	87.143
Alumina,	5.666
Oxides of iron,	2.220
Oxides of manganese,	0.360
Lime,	0.564
Magnesia,	0.312
Potash and soda,	0.145
Phosphoric acid,	0.060
Sulphuric acid,	0.027
Chlorine in common salt,	0.026
Humic acid,	1.304
Insoluble humus,	1.072
Organic matters containing nitrogen,	1.011
Carbonic acid united to the lime,	0.080

ANALYSIS OF A SANDY SOIL, UNFIT FOR CULTIVATION.

Silica and quartz sand,	96.000
Alumina,	0.500
Oxides of iron,	2.000
Oxides of manganese,	trace.
Lime,	0.001
Magnesia,	trace.

ANALYSIS—*Continued.*

Potash,	do.
Soda,	do.
Phosphoric acid,	do.
Sulphuric acid,	do.
Carbonic acid,	——
Chlorine,	trace.
Humic acid,	0.200
Insoluble humus,	1.299
Water,	——
	100

Chemically considered, a soil must contain all the inorganic elements which plants require, and none that are injurious to them. If the addition of a certain manure render a soil more fertile, it is evident that the soil was deficient in one or more of those substances which it furnished. If the addition of a given manure or salt to a defective soil, fail to improve its fertility, it is because enough of this substance is already present, or because some other substance is wanting to render this application available. A soil may sometimes show more or iess fertility for certain crops than analysis would indicate, on account of some mechanical and physical conditions: in this way the supply of certain elements may be cut off, although they are present in the soil: the deficiency of others may also be partially compensated by the same causes.

CHAPTER IX.

MECHANICAL PHILOSOPHY.

Mechanical philosophy treats of the equilibrium and motion of bodies: its great object of inquiry is, into the causes which produce or prevent motion, and the manner in which it takes place. "That part of mechanics which relates to the action of forces producing equilibrium or rest, in bodies, is called *statics;* that which relates to the action of forces producing motion is called *dynamics.*"

The practical value of this branch of science consists in the application of a few simple mechanical powers, either single or combined in some kind of machinery, in overcoming resistances, and producing and applying motion to useful purposes.

"*Power* is the means by which a machine is moved and force attained; thus we have horse power, water power, steam power, &c.

Force is the means by which bodies are set in motion, kept in motion, and when moving are brought to rest. The force of gunpowder sets a ball in motion and keeps it moving until the resisting force of the air, and the force of gravity bring it to rest."

A few simple instruments or machines variously combined, produce all the complicated, powerful and beautiful pieces of machinery which have ever been constructed.

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These few elementary powers are, the lever, the wheel and axle, the pulley, the inclined plane, the wedge and the screw.

The *lever* is a straight bar placed upon a supporting point called a fulcrum, with the resistance which is to be overcome, at one end, and the power applied, at the other.

The *wheel and axle* is somewhat more complex than the lever; it consists of two concentric wheels, one of which is larger than the other, and both revolving on a common axis. This power acts like a succession of levers, and is therefore a a modification of the lever.

The *pulley* consists of a flat disc, with a groove on the edge, through which a rope passes, and a hole in its centre, through which a fixed axis passes, on which it revolves: when several pulleys are combined, they constitute a system of pulleys, or a compound pulley. The power of a system of pulleys increases in proportion to the number of pulleys employed.

The *inclined plane*, as its name implies, consists merely of a plane surface, with one of its ends higher than the other, so that the plane forms an angle with the horizon.

The *wedge* may be considered as two inclined planes with their bases placed together, and their apices forming an acute point. The power of the wedge depends upon its relative length compared with the width of its base,—or upon the degree of taper from the base to the point.

The *screw* is the sixth mechanical power, and may be considered a continuous spiral wedge, or a modification of the inclined plane. The power of the screw depends upon the relation between its circumference and the distance between its threads.

OBJECTS AND ADVANTAGES OF MACHINERY.

No actual power is ever generated by machinery; force and velocity may be gained, but they are always gained at the expense of the motive power applied to work the machine: the power and force must always be in exact proportion to each other, so that, if one is increased, the other is diminished in the same proportion. Great velocity in a machine, or in any of its parts, is incompatible with great power also; for whatever is gained in speed is lost in strength,—that is, it is gained at the expense of power or force.

It is not expected to gain power, force and velocity at the same time by the use of any mechanical contrivance whatever, —but, by taking a philosophical advantage of the few simple mechanical powers, to obtain one or the other of them, according to the labor to be performed.

The advantages of machinery are numerous.

1. By the aid of machinery we can apply force to much better purpose than by our unassisted hands.

2. A man can perform a work by its aid, to which he would be wholly incompetent without it.

3. It often enables men to exert their whole force, where without it they could exert only a small part of it.

4. It enables us to employ animals in the execution of many kinds of work which must otherwise be performed by man himself.

5. It enables us to employ several inanimate motive powers, such as water, steam, wind, heat, electricity, &c.

6. Many manufacturing operations are performed with much greater facility and exactness than they could be by hand.

7. Machinery saves a considerable part of the materials used in the manufacture of many fabrics.

ON REGULATING THE MOTION OF MACHINERY.

The motion of machinery, to operate to the best advantage, should be perfectly regular and uniform. Variations of motion consist principally in variations of power, weight or resistances, and changes of velocity in different parts of the machine itself. The different instruments used to obviate these effects, and secure uniform motion, are called regulators. There can be little doubt that water, where it is abundant and available, furnishes the most economical motive power, and one which propels machinery with greater uniformity than any other which we possess.

Among the instruments used for modifying and regulating motion are, the *fly wheel, governor, ratchet wheel, universal joint, crank, eccentric wheel, arch head, pendulum, knee joint, fusee,* &c.

Every part of a machine ought to be proportioned to the stress it is to bear, and the strength it requires,—and should be no heavier than necesssary: all parts should bear their relative proportion of the work and wear, so that when the machine fails, all parts shall be worn out. Every machine should consist of as few parts as possible; because, when parts are multiplied, friction is increased in the same proportion, and the machine is more liable to get out of repair. All mechanical obstacles and errors have a less ratio to the motion in great than in small machines; the former, therefore, work with more uniformity and exactness, but are proportionally weaker and more liable to be broken.

Motion and rest are both equally accidental states of matter: bodies are no more disposed to lie at rest than to put themselves in motion: they maintain a state of rest so long as there is an equilibrium of all the forces acting upon them; and when they assume a state of motion, it is because they are acted upon by some extrinsic force, which is stronger than the combined action of all those which tend to keep them at rest. When once in motion, bodies would continue moving forever, if no force obstructed them to destroy the equiblirum between accidental resistances and the propelling force: in other words, they never would come to rest, unless brought to rest by some power superior to that which set them moving.

Motion may be *absolute* or *relative:* absolute motion is a change of place by a body, in relation to some fixed point:

relative motion is a change of place by a body in relation to some other body which is in absolute motion.

Simple motion results from the action of a single force upon a body, while compound motion is produced by two or more forces acting different directions. Motion, when once attained would be onward in a straight line unless changed or destroyed by some force secondary to the one by which it was produced: a ball projected from a cannon, assumes a curved line towards the earth, because acted upon by the attraction of gravity; and this sufficiently strong to overpower the propelling force of the powder which gave it motion, and finally bring it to rest.

OBSTRUCTIONS TO THE ACTION OF MACHINERY.

Friction arises mostly from the elevations of one surface entering into the depressions of another; but partly also from the mutual cohesion of the surfaces.

Sliding friction is produced when pinions or axes revolve on their support.

Rolling friction occurs when a round ball or wheel rolls along a surface. Friction is greater between two surfaces of wood where their fibres lie parallel than where they run across each other: it is also greater between two surfaces of the same metal than between those of different metals: two surfaces of iron would produce more friction than one of copper and one of iron: cast steel is said to be an exception to this rule.

The ristance of friction may be diminished by the use of fine smooth and oily substances; the particles of which fill up the cavities and lubricate the asperities of the surfaces. For this purpose oil is best adapted to metals and tallow for wood.

Extent of surface makes no difference, in a given body, in regard to the amount of friction developed. Friction is increased between two bodies by their remaining some time in contact; in some cases it does not attain the maximum in four or five days. In the contact of two metals, the friction attains its highest point in a few seconds: two pieces of wood attain their utmost friction in one or two hours: when iron runs upon oak the friction will increase for four or five days.

Friction is less after motion becomes well established and rapid, than when it first commences. The whole efficacy of the screw depends upon the friction between the threads of the external and internal screw: the screw being an inclined plane, if there was no friction, it would unscrew, or the internal screw would descend by its own gravity when placed vertically. Query? What relation has the development of friction to electricity?

The resistance of the atmosphere, which in some machines must be considerable, is another obstruction to the action of machinery. The weight or gravity of a machine itself, or of some of its parts, is sufficient in some cases to require a considerable part of its power to overcome it.

STRENGTH OF MATERIALS.

It is important, in the construction of all pieces of architecture and machinery, that the mechanic should know the strength of the materials which he is to employ in the work. By *strength*, we understand the power which a body has, by the cohesive force of its particles to resist fracture: *stress* is the power or tendency in a body to produce fracture by its own weight.

A *joist* eight inches wide and two inches thick, is four times as strong when laid on its edge as when laid on its side.

"A *triangular beam* is twice as strong when resting on its broad base as when resting on its edge."

"The strength of a *column* in the direction of its length, is directly proportional to the area of its transverse section."

"Half the length of a *beam* supported at both ends, will bear four times as great a pressure as the whole beam; and a prop placed under the centre of a beam increases its strength in the same ratio."

The strength of a beam increases from the centre towards the ends or points of support, and the stress increases from the ends towards the centre; hence, a beam to be equally strong at every point, should be eliptical, or the largest in the middle and taper regularly towards both ends.

The strongest form in which a given quantity of matter can be disposed, is that of a hollow *cylinder:* this, however, is true only when the transverse sections of the cylinder are perfectly circular. In this way nature economizes material, avoids too great weight, and at the same time augments strength.

"A great column is in greater danger of being broken than a similar small one; an insect can sustain a weight many times greater than itself,—whereas a much larger animal, as a horse, could scarcely carry another horse of his own size."

It is not regarded as safe to load a stone structure with more than one-sixth the amount of pressure which it requires to crush it: iron may be loaded to one-fourth that amount. In building *bridges,* &c., which are to span considerable space without as much support as might be desirable, it is important to calculate accurately, both the strength and stress of the beams: bridges apparently strong, and perfect in construction, sometimes fall by their own weight: in such cases there is an unnecessary violation of a philosophical principle of which no mechanic should be ignorant. For *suspension bridges,* the strongest material for spanning a wide stream is cast steel wire,—the next strongest is malleable iron, and least of all metals, lead. A piece of cast steel wire one-eighth of an inch in diameter will sustain a weight of 16,782 pounds; or 4,931 feet of its own length: malleable iron wire of the same size, 9,008, or 2,467 feet of its own length: lead wire of the same size sustains only 228 pounds, or 42 feet of its own length.

Of the different kinds of wood, the strongest are, the ash, oak, teak, beech and larch,—the strongest of these is the ash.

We see by these few facts in relation to mechanical philosophy, that almost every practical mechanical operation can be reduced to scientific rules, and the result calculated with mathematical certainty before the work is commenced. We see also how much more easily and economically many operations might be performed, and how much disappointment and money might be saved by a knowledge of this branch of science, to the visionary inventors of patent rights, the only fault of which is, that they refuse obstinately to perform any part of the work designed for them,—and the greatest misfortune of whose inventors is their ignorance. A knowledge of mechanical philosophy is indispensible to the accomplished mechanic or agriculturist.

GLOSSARY.

Agriculture, the science and art of productive farming.

Affinity, attraction—that force which causes two bodies of different properties to unite and form a compound.

Annual, yearly.

Aerial, pertaining to the air.

Axis, the centre or point on which a body does or may revolve.

Acotyledonous, without a colyledon.

Appendage, something added.

Albumen, an organic principle resembling white of eggs.

Altitude, height or elevation.

Arterial, pertaining to the arteries.

Acerose, needle shaped.

Axillary, growing in the angle between the stem and leaf.

Arragonite, a simple mineral composed of carbonate of lime.

Ament, flowers collected on chaff-like scales and arranged on a slender stalk.

Assimilate, to become similar.

Anemia, want of blood—in botany want of sap.

Absorption, the act of imbibing or absorbing.

Anthracite, a species of mineral coal.

Aluminum, a metalic earth, the base of alum.

Albite, a species of feldspar.

Arseniate, a salt of arsenic.

Asbestos, a fibrous incombustible mineral.
Analysis, separating the elements of a compound.
Azure, sky blue.
Alluvium, the sediment of rivers such as sand, vegetable matter, mud, &c.
Augite, a simple mineral of a dark green or black color, found as a constituent in many volcanic rocks.
Amygdaloid, one of the trap rocks through which are scattered agates and simple minerals.
Agate, a translucent silicious mineral of many varieties.
Apocrenic acid, an acid found in peat and humus soils.
Atmosphere, the air which we breathe.
Aggregate, the sum of several particulars.
Anhydrous, destitute of water.
Aurora Borealis, Northern Lights.
Aqueous, watery.
Aerolite, a meteoric stone falling through the air.
Alternate, leaves growing on opposite sides of the stem at different distances, but not opposite each other, are alternate.
Alburnum, sap-wood.
Accretion, increasing in size by the addition of new matter.
Alchemy, the pretended science from which chemistry originated: its operations consisted in trying to change the baser metals into gold; to find a universal solvent and a remedy for all diseases.
Attenuation, the act of making fine, thin, minute.
Angle of incidence, the angle at which a moving body strikes another.
Angle of reflection, the angle at which a moving body leaves or bounds from another.
Aquafortis, nitric acid.
Aqua-ammonia, spirit of hartshorn.
Acrid, sharp, pungent, biting.
Acid, sour, having chemical properties opposite to alkalies.

Alkali, in common language, lye.
Apotheme, extractive matter.
Adjective colors, such as require a mordant.
Alizarine, the basis of the red coloring principle.
Arable, fit for tillage or cultivation.
Avidity, greediness, eagerness.
Asboline, one of the elements of soot.
Botany, the science of plants.
Boulder, a rounded fragment of rock lying on the surface.
Blowpipe, an instrument used in chemical experiments.
Bole, a species of reddish earth.
Bitumenization, the process of furnishing bituminous coal.
Biennial, once in two years.
Biternate, twice ternate,—two petioles, each bearing three leaves.
Barometer, an instrument for measuring the pressure of the atmosphere.
Base, the substance which combines with an acid to form a salt.
Bed, a term used in Geology to denote the extent of a stratum of coal or other rock.
Basalt, a dark green rock divided in columns.
Climatology, a treatise on climate.
Caloric, the agent which produces heat.
Coalesce, to unite or run together.
Condense, to make more dense.
Clouds, floating particles of water or other matter.
Congeal, to freeze or harden.
Crystalization, the act of forming crystals.
Concentric, having a common centre.
Cohesion, the force which holds the particles of bodies together.
Corona, a luminous circle round the sun or moon.
Cleavage planes, the flat surface formed by the cleavage of rocks.

Continuity, unbroken, continuous texture.

Carboniferous, any bed or rock containing coal.

Coral, a maritime production composed of lime, and the habitation of insects.

Cuboidal, in the form of a cube: square.

Columnar, having the form of columns.

Chalcedony, a species of quartz-like mineral.

Calcareous spar, crystalized carbonate of lime.

Crater, the opening of a volcano through which its eruptions take place.

Chlorite, a simple mineral of a green color.

Crucible, an earthen or metallic pot, in which ores are melted and purified.

Crenic acid, an acid found in peat and humus soils.

Calcareous, limy, composed mostly of lime.

Caustic, corrosive, biting, burning.

Calcine, to burn.

Cuticle, the outside bark or skin.

Capillarity, the property of absorbing by capillary attraction.

Carbonate of potash, pearlash.

Chlorine, a simple substance.

Calorific, producing heat.

Capacity for caloric, power of containing latent heat.

Combustion, the act of burning.

Conductors, substances which conduct caloric or electricity.

Carbon, charcoal.

Clarify, to make clear or clean.

Carbonic acid, a compound of carbon and oxygen.

Complex, having many component parts.

Coniferous, bearing seeds in cones, like the pine.

Carmine, a coloring matter of a pink color.

Casiene, an organic element the basis of cheese.

Caramel, a substance produced by heating sugar.

Carburetted hydrogen, a gas composed of carbon and hydrogen.

Carbonic oxide, a gas composed of carbon and oxygen.
Corrosive, having the property of corroding and destroying.
Cellular, composed of small cells.
Cryptogamous, having flowers too minute to be seen with the naked eye.
Cotyledon, a seed lobe.
Carnivora, the class of animals which live on flesh.
Cruciform, having the form of a cross.
Calyx, a cup, the bottom part of a flower.
Corolla, the closed leaves of a flower.
Crude, raw, immature.
Cordate, heart shaped.
Chlorophylle, the green coloring matter of plants.
Cambium, the descending sap which forms wood.
Centripetal, tending towards the centre.
Cereals, the white straw grains, as wheat and rye.
Chrysolite, a simple mineral, of gold color.
Centrifugal, tending to recede from the centre.
Corymb, a cluster of flowers whose stalks spring from different heights, and form a flat top.
Cyme, a cluster of flowers whose stalks rise from a common centre, and afterwards subdivide irregularly.
Contagion, an infectious or pestilential disease which is communicated by contact or through the atmosphere, from one animal or plant to another.
Denude, to make naked or bare.
Dunes, hills of blown sand.
Disintegrate, to separate into integral parts.
Ductile, capable of being drawn into wire.
Dilute, to make thin or reduce in strength.
Deciduous, falling off in the usual season: not persistent.
Dissemination, the act of sowing or scattering.
Dilate, to expand, extend, enlarge.
Digestion, the act of assimilating food to the body.

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Digitate, divided like the fingers.

Dip, the inclination of a stratum of rock from the horizon.

Dyke, a mass of rock which appears to have been injected into the fissures of other rocks.

Drift, masses of sand or other matters driven together by water.

Deleterious, injurious, noxious.

Duramen, the inside, brown heart of wood of forest trees.

Decompose, to separate into parts or elements.

Data, known or admitted facts or principles.

Deutoxide, a chemical compound containing two proportions of oxygen.

Daguerreotype, a process of taking pictures by means of light.

Dynamical, pertaining to strength or power.

Deliquiesce, to dissolve gradually by attracting and absorbing moisture from the air.

Distillation, separating essential oils or alcohol from other matters, by means of heat.

Diurnal, daily, occurring daily.

Disinfecting, purifying and preventing contagion or infection.

Extant, now in use.

Extirpate, to destroy or eradicate.

Excavate, to dig or wear out a hollow or cavity.

Excrements, matters voided or excreted by animals.

Endogens, plants which grow from the inside.

Electricity, a principle in nature usually called lightning.

Elasticity, power of resuming form after compression.

Elective affinity, that affinity which causes an acid or alkali to abandon one with which it is already united, and unite with another.

Ether, a subtil matter which is much lighter than air, and supposed to exist beyond the limits of the atmosphere.

Emit, to send off, give out or discharge.

Expansion, the act of enlarging or increasing in bulk.

Equivalent number, the particular quantity of any substance required to combine with or saturate another substance.

Emanate, to issue or flow from.

Electric, a substance capable of giving off electricity.

Electrical repulsion, that property which causes bodies in the same state of electrical excitement to separate: opposite attraction.

Exude, to run out or issue from.

Equilibrium, balance of forces or properties.

Epiphytes, plants growing upon the trunk and branches of other plants and deriving nourishment mostly from the air.

Epidermis outside skin or bark.

Excrete, to eject or throw out.

Embryo, the germ of a plant or animal.

Elliptical, an oval figure with pointed ends.

Exogens, plants which grow by layers on the outside.

Exhalation, breathing out, giving off, emitting.

Evolution, emission, giving off, discharging.

Element, a component part, first principle.

Equator, an imaginary line dividing the earth into two halves; the equinoctial line.

Effloresce, to become a dry powder.

Eremacausis, slow combustion or decay.

Evaporation, becoming volatile, flying off with the air, drying up.

Escarpment, a steep ledge of rocks.

Eurite, a white mineral.

Eject, to throw out, discharge.

Effervesce, to foam, bubble, ferment.

Fasicle, a small bundle.

Flora, the goddess of flowers, a flower or book of flowers.

Functional, pertaining to the office or use of a part of any organism.

Filament, the slender, thread-like part of the stamen.

Fibrils, minute branches of roots.

Fibrous, composed of fibres.

Fusiform, spindle-shaped, tapering.

Fasciculated, collected in heads or bundles.

Fundamental, original, elementary, first principle.

Fructification, the flower and fruit with their parts, the act of making fruitful.

FAHRENHEIT, the inventor of the thermometer which bears that name.

Fault, a cleft or fissure in a rock.

Fossil, the remains of animals and plants found buried in the earth.

Formation, a group of any kind of rocks referred to a common origin or period.

Fossiliferous, containing fossils.

Fissure, a crack or cleft.

Fuse, to melt, become fluid from heat.

Faggot, a bundle of sticks or brush.

Friable, easily crumbled or pulverized.

Fertilizers, substances used to enrich the soil.

Focus, the point at which rays of light or heat meet.

Fluor spar, a mineral compound of lime and fluoric acid.

Fibre, a slender, thread-like organ or substance.

Fumes, vapor, gas or smoke.

Freezing point, this is placed at 32° Fahrenheit.

Feldspar, a simple mineral which constitutes a principal ingredient of most rocks.

Fire damp, light carburetted hydrogen.

Fibrine, the colorless part of the blood which when separated from it becomes jelly-like.

Geology, the science of the earth's structure, &c.

Graphite, black lead.

Galvanism, a species or modification of electricity.

Glutinous, sticky, visced, having the characters of glue.

Generate, to produce or create.

Gelatine, a proximate principle in plants and the bodies of animals, usually called jelly.

Guano, a species of manure composed mostly of the excrements of sea fowl.

Granite, an unstratified primary rock.

Greenstone, a variety of trap rock composed of hornblende and feldspar.

Gneiss, a primary stratified rock composed of the same materials as granite.

Garnet, a simple crystalized mineral, generally of a deep red color.

Gypsum, plaster of paris, sulphate of lime.

Graphic granite, is a species of granite in which the quartz is so arranged as to give the surface the appearance of having letters.

Gorge, a deep fissure or valley.

Gyration, turning in a circular or spiral direction.

Glossology, the application of names to the various organs of plants.

Granulated, consisting of small grains, granules, or masses.

Genus, the subdivision of an order.

Gland, an organ in animals and vegetables which performs the function of secreting a fluid.

Germination, the unfolding of the seed and development of the embryo.

Geine, a substance obtained from decayed wood, and containing an acid called the geic acid.

Glanular, consisting of grains.

Graywacke, an ancient fossiliferous rock, generally of a gray color.

Gravity, weight: specific gravity, the weight of a particular body compared with some standard.

Gas, an elastic fluid, or air.

Gelatinous, containing gelatine.
Homogeneous, of the same nature, consisting of similar parts, all alike in structure.
Hornblende, a simple mineral of dark green or black color.
Humid, moist, wet.
Harmattan, a dry easterly wind in Africa.
Haziness, foggy, smoky, misty.
Horizon, the line where the earth and sky appear to meet.
Hydrogen, a gas, the lightest of all known bodies.
Hues, tints, colors.
Hurricane, a violent storm or tempest.
Halo, a circle appearing around the sun, moon, or stars.
Hypothesis, a supposition or theory assumed but not proved: used for the purpose of argument.
Hexagonal, six sided: having six sides and six angles.
Hydracid, an acid formed by the union of a substance with hydrogen without oxygen.
Hematoxyline, the coloring principle of logwood.
Hydrate, a compound containing water.
Humic acid, an acid obtained from humus.
Herbaceous, herb-like, not woody.
Herbarium, a book in which dried plants are preserved.
Imbibe, to take in, absorb.
Irrigation, the act of watering, moistening.
Incineration, the act of reducing to ashes.
Intersect, to meet and cross each other.
Isomeric, bodies which differ in properties but agree in composition.
Interstratified, stratified between or among other bodies.
Infusible, that cannot be fused or melted.
Incas, inhabitants of Peru and some other parts of S. America.
Inflate, to blow up, fill with wind.
Isothermal lines, lines which pass through points on the surface of the earth at which the mean temperature is equal.

Isochimenal lines, lines passing through points on the earth at which the mean temperature of the winter is equal.

Intertropical, between the tropics.

Ignis fatuus, Jack O'Lantern.

Inverted, turned upside down.

Igneous, rocks, such as have been melted by fire or volcanic heat.

Infusoria, animalcules too minute to be seen by the naked eye.

Interlace, to tangle or lace together.

Inflorescence, the manner in which flowers are connected with the plants.

Indigenous, native of, or growing wild in a country.

Joint, the parting lines in rocks, often at right angles with the planes of stratification.

Kaolin, a species of potter's clay.

Lignite, wood converted into a kind of coal.

Lava, the melted stone which is thrown out of volcanoes.

Lichens, cryptogamic plants, of a crusty texture, growing on rocks and the trunks and branches of trees.

Lenticular, having the form of a lens.

Longevity, length of life.

Laticiferous, the system of vessels in the bark of plants, which circulates their fluids.

Latex, the fluid formed from the sap, and which nourishes all parts of plants.

Lanceolate, in the form of a lancet.

Lyrate, pinnatified with a large roundish leaflet at the end.

Linear, long and narrow with parallel sides, as in the leaves of the grasses.

Leguminous, having legumes or pods, as the bean and pea.

Liber, the inner bark of plants.

Lamina, layers, thin plates or leaves.

Longitude, the distance of places on the globe in an east and west direction.

Latitude, distance or degrees north and south.

Laminated, in lamina, layers or leaves.

Lunar, pertaining to the moon.

Limpid, pure, clear, transparent: thin when used in reference to some fluids.

Marine, pertaining to the sea.

Microscopic, objects which are too small to be seen without the aid of the microscope.

Macerate, to soak, dissolve.

Maximum, the greatest number or quantity attainable in any given case.

Magnetism, the power or force which causes the magnetic needle to point north and south.

Molecules, the ultimate or minute particles of matter.

Mirror, a looking-glass.

Mercury, quicksilver.

Mucilage, a slimy fluid, one of the proximate elements of plants.

Mordant, any substance used by dyers to set colors, or render them permanent.

Must, the juice of grapes which has not fermented, new wine.

Metamorphosis, change, transformation.

Meteorology, the branch of science which treats of changes of weather and other atmospheric phenomena.

Meteor, any appearance or phenomena observed in the atmosphere.

Mean temperature, that point which lies midway between the two extremes of heat and cold.

Mist, fog, vapor.

Maritime, relating or pertaining to the sea.

Monsoon, a periodical wind which blows six months in one direction, and then changes and blows six months in the opposite direction.

Moor, a marsh or fen, or land overgrown with heath and other shrubs.

Mirage, an optical illusion described in meteorology.

Mineral, in common language, the metals and rocks.

Metalloid, a name applied to some of the metallic bases of the earths.

Mica, a rock which is divided or laminated in its shining scales, and of various colors.

Metamorphic, rocks which have been altered by the action of fire.

Muriate of magnesia, a salt formed by the union of magnesia with muriatic or hydrochloric acid.

Mammalia, vertebrated animals, which have warm blood, breathe by means of lungs, bring forth living young and nourish them by milk.

Membrane, a thin delicate skin.

Midrib, the main or middle rib of a leaf, running from the base to the point.

Medullary, pertaining to the pith or marrow.

Morphology, that part of botany which treats of the formation and metamorphosis of organs.

Malleable, a metal which can be hammered and drawn out into various forms by the hammer, as iron.

Nutrient, nourishing, or pertaining to nutrition.

Noxious, hurtful, injurious, unwholesome.

Nomenclature, a system of naming or applying technical terms in any art or science.

Nutrition, the act or process of supplying the proper matter for the growth of animals and plants.

Nitric acid, aquafortis.

Nitrate of potash, salt petre.

Node, a knot or protuberance.

Nocturnal, nightly, occurring every night.

Nickel, a grayish white brittle metal.

Nodular, having nodes or knots.

Napiform, resembling a turnip in form.

Ovary, a name in botany given to the outer covering of the germ.

Ovules, little eggs, the rudiments of seeds which the germ contains before its fertilization.

Orbicular, round, circular.

Organography, a description of the organs of plants.

Organic, composed of various parts or organs which perform separate offices.

Oxidize, to become rusty or combine with oxygen.

Observatory, a place or building for making observations on the heavenly bodies.

Opake, not transparent, not pervious to rays of light.

Optical, pertaining the eye, to vision, or the science of optics.

Orbit, in astronomy, the path of a comet or planet.

Outcrop, the naked ends of strata of rock which protrude above the surface of the earth, as on the side of a hill.

Oolite, a limestone composed of rounded particles like the eggs of fish.

Organic remains, the fossil remains of plants and animals.

Olivine, an olive colored simple mineral often found in grains and crystals in basalt and lava.

Oxide, a chemical compound of metals with oxygen, &c.

Oxygen, a gas.

Oxalate, a salt composed of oxalic acid and a base.

Oxalic acid, an acid obtained from sorrel.

Ordure, excrement, fæces, manure.

Permeate, to penetrate or pass through the pores of a body.

Phosphuretted Hydrogen, a compound of phosphorus and hydrogen.

Poudrette, a manure prepared from ordure.

Philosopher's stone, an imaginary mineral sought by the alchymists, which was supposed to be capable by mixture with the baser metals of transmuting them into gold.

Proximate, near; "proximate elements," those elements of plants, such as starch, gum, &c., which are composed of the immediate elements, viz: the gases and mineral matters.

Protoxide, a compound containing one proportion of oxygen.

Photographic, pertaining to light; photographic pictures are taken by light.

Phosphorescence, a peculiar luminous matter without fire or combustion, as the light given out by phosphorus, decayed wood, putrifying flesh, &c.

Parábola, a conic section arising from cutting a cone by a plane parallel to one of its sides.

Prism, in optics, a triangular glass instrument for separating the rays of light.

Polarity, that property which causes one end of a body to repel and the other to attract, as in bodies magnetized or electrified; pointing towards the poles.

Putrefaction, decomposition or decay of organic bodies.

Pungent, biting, hot, sharp.

Ponderable, possessing weight.

Precipitate, to throw down or separate.

Phosphates, compounds containing phosphorus.

Parallelism, the state or quality of being parallel.

Petrify, to become stone.

Pebble, a small stone.

Plutonic, pertaining to subterranean heat.

Porphyry, an unstratified igneous rock.

Pegmatite, primitive granite rock.

Pumice stone, a species of lava.

Plumbago, black lead, graphite.

Pulverulent, consisting of fine dust or powder.

Phenomena, an appearance.

Phase, an appearance, exhibited by the illumination of the moon or other planets.

Polar elevation, height of latitude, or approach towards the poles.

Pestilential, infectious, spreading pestilence.

Phosphorus, a simple combustible body of a yellowish color, and the consistence of beeswax.

Physical, pertaining to matter or physics.

Parhelia, mock suns, or luminous spots near the sun.

Pistil, the central organ of most plants consisting of the stigma, style and germ.

Perianth, a sort of calyx, the floral envelops, consisting of the calyx and corolla, which are placed around the pistils and stamens.

Pollen, the dust contained within the anthers of flowers, and necessary to fructification.

Placenta, a part of the ovary to which the ovules are attached.

Pericarp, the seed covering.

Parasite, a plant or animal which grows on another.

Perennial, lasting more than two years, evergreen.

Phenogamia, plants which bear visible flowers.

Petal, a flower leaf which is part of the corolla.

Plumule, the ascending part of a germinating plant.

Perforate, to make a hole, having holes, to pierce.

Parenchyma, the principal and proper substance of any organ in a plant or animal.

Pervious, porous, or capable of being penetrated.

Pellicle, a thin skin, film or crust.

Pyrogen, the matter or generator of electricity.

Porcelain, a fine kind of earthen ware.

Peat, decayed and decaying vegetables, usually buried below the surface of the ground.

Peduncle, the stem which bears the flower and fruit.

Panicle, a loose, irregular bunch of flowers, as in the oat.

Propagate, to produce, or multiply by shoots, &c.

Physiology, the science which explains the laws of life and the uses and offices of all the various organs of plants and animals.

Pulp, the soft juicy part of fruits and berries.

Quartz, a simple mineral composed of silex or flint.

Quartzose, containing quartz.

Quiescent, in a state of quietude or repose.

Quadruple, four times, four fold.

Radiate, to shine, to proceed in direct lines from a point, like rays of light or heat.

Repulsion, the act of repelling or driving off, as in bodies in the same electrical state: opposed to attraction.

Rarity, the opposite of density, thin, light.

Refrangibility, capable of being refracted.

Respire, to breath.

Residual, remaining after a part is taken, sediment which subsides from a watery mixture.

Reagent, a substance employed to precipitate another from solution, or to detect the presence of some other substance.

Rape, a plant of the genus brassica, allied to the cabbage.

Ramify, to branch off, divide.

Radiation, the act of radiating, throwing off rays.

Refrigerating, producing cold.

Reverberate, to return, rebound, resound, re-echo.

Rays of light, the brilliant luminous lines which proceed or radiate from a luminous body.

Rarify, to make less dense, to make thin or light.

Rarifaction, the process of rarifying, making more porous by expansion.

Refraction, the act of bending or breaking, diviating from a direct course, as in rays of light.

Receptacle, the end of the flower stalk to which the organs of fructification are usually attached.

Ramous, branching, having lateral divisions.

Ramification, branching, minute division.

Ravine, a deep hollow or valley worn out by water.

Ruby, a precious stone, a simple mineral of a carmine red color.

Rachis, the common stalk to which florets and spikelets are attached, and in the grasses and wheat.

Raceme, a cluster, that variety of inflorescence in which the flowers are arranged by simple pedicels on the sides of a common peduncle, as the currant.

Respiration, breathing, or the act of absorbing or inhaling, and exhaling carbonic acid and oxygen.

Rosacea, an order of plants, including the rose tribe.

Radicle, the descending part of a germinating plant, a small root.

Rudimental, consisting of the first principles, or simple elementary parts.

Reniform, kidney shaped.

Silicate, a salt containing silica united to a base.

Silecious, containing silex.

STERCOLOGY, the science of manuring, enriching, or improving the soil.

Smoulder, to burn and smoke without vent.

Sewer, a drain to convey off water underground.

Sulphate of iron, green vitriol, copperas.

Spurry, a plant of the genus spergula, allied to chickweed and tares.

Spiral, in the form of a screw, gyratory like the thread of a screw.

Subordinate, of minor importance, a secondary or inferior part.

Synthesis, the act of combining, contrary to analysis.

Spectrum, a visible image continuing after the eyes are closed: the seven primary colors constitute the solar spectrum.

Statical, in a state of rest, the branch of mechanics which treats of bodies at rest.

Sterile, barren, unproductive.

Solvent, a substance or fluid which dissolves other substances.

Safety lamp, a lamp surrounded by wire gauze, invented by Dr. Davy to prevent explosions from the ignition of gas in coal mines.

Solar, pertaining to the sun.

Sublimated, brought into a state of vapor by heat.

Stamen, a slender threadlike organ in the centre of flowers.

Summit, the apex or top.

Stigma, the summit or top of the pistil.

Style, the part of the pistil between the stigma and germ.

Stomata, mouths, or orifices.

Spongioles, the minute spongy suckers or extremities of roots.

Spores, the seeds of cryptogamous plants, bodies analagous to the pollen grains of flowering plants.

Sepal, a leaf of the calyx.

Sagittate, arrow form.

Segment, a part or principal division of a leaf, calyx, or corolla.

Stellate, star form.

Succulent, juicy.

Shale, a solid form of clay, which usually divides into lamina.

Saccharine, sweet, containing sugar.

Spadix, an elongated receptacle of flowers, commonly proceeding from a spathe.

Scoria, volcanic cinders.

Silicon, the substance which combined with oxygen constitutes silicic acid or flint.

Sapphire, a hard mineral, consisting of crystalized alumina: it is of various colors; the *blue* being generally called the sapphire; the *red,* the oriental ruby; the *yellow,* the oriental topaz.

Saline, salt, containing some salt.

Sodium, the metallic base of soda.

Steatite, soapstone, a hydrated silicate of magnesia and alumina.

Snow-line, the lowest point on mountains at which there is perpetual snow.

Subterranean, underground, below the earth's surface.

Submerge, to plunge under water, to overflow.

Strata, layers of rock.

Spherule, a little sphere, or ball.

Simoon, a hot suffocating wind, that blows occasionally in Africa and South America.

Sirocco, a pernicious wind that blows from the south-east in Italy.

Salubrious, healthful, favorable to health.

Supernatural, miraculous, out of the usual course of nature.

Solar spectrum, the seven primary colors as seen in the rainbow.

Stratified, arranged in strata or layers.

Silurian, a series of rocks forming the upper subdivision of the sedimentary strata found below the old red sandstone, and formerly designated the graywacke series.

Scape, a stalk which springs from the root, and supports flowers and fruit, but no leaves.

Saturate, to fill with a fluid, absorb, soak.

Sedimentary rocks, are those which have been formed by their materials having been thrown down from a state of suspension or solution in water.

Syenite, a kind of granite so called because it was formerly brought from Syene in Egypt.

Serpentine, a rock usually unstratified, containing much magnesia, and often speckled of various colors, like a serpent's back.

Sculpture, the art of carving wood or stone into the images of men or animals.

Stucco, a fine white plaster, to plaster with stucco.

Stalactite, a variety of carbonate of lime in the form of icicles, produced by the filtration of water containing lime in solution, from the crevices of rocks in the roofs of caverns.

Stalagmites, are similar to stalactites, but formed by the dropping of water on the floors of caverns, and having their points upwards.

Twilight, the light at the close of day after sunset and before dark.

Tortuous, crooked, convoluted.

Tertiary, a series of sedimentary rocks, lying above the primary and secondary, and having characters which distinguish them from these two classes.

Trachyte, a variety of lava essentially composed of greenstone: it frequently contains detatched crystals of feldspar, and sometimes hornblende and augite.

Titaniferous, an iron ore containing titanium.

Talc, a species of magnesian earth, consisting of smooth shining lamina, translucent or transparent.

Transparent, admitting rays of light to pass through.

Transverse, crosswise, across.

Terrestrial, belonging to, or pertaining to the earth.

Tillage, includes all mechanical operations on the soil.

Tropical, belonging to the tropics.

Torrid zone, the hot country included between the Tropic of Cancer, and the Tropic of Capricorn.

Tornado, a high wind, a whirlwind.

Theory, an exposition of the principles of any science; the science without the art or practice.

Tissue, connection or organization, the proper substance of an organ.

Terminal, situated at the end.

Thyrse, a loose irregular bunch of flowers.

Tenacity, toughness, having strong cohesion,

Tap root, the main root, the axis.

Tuber, a fleshy knob or tumor on a root.

Trifolium, the genus of plants to which clover belongs.

Ternate, leaves which are arranged in threes are called ternate.

Transmit, to permit to pass, to convey through.

Tint, shade, hue, color.

Transition, rocks which appear to have been formed while the earth was in a state of transition, from a state of desolation to a habitable condition. They have a texture partly mechanical and partly chemical.

Urea, the principal element, next to water, in the composition of the urine.

Ulmic acid, a substance formed by the action of acids on sugar.

Unconsolidated, soft, not consolidated.

Umbel, a kind of infloresence in which the flower stalks diverge from one centre, as the wild parsnep.

Volcano, a burning mountain.

Vision, sight, the act of seeing.

Veins, cracks or fissures in rocks which are filled with substances different from the rock, either mineral or earthy.

Volcanic, pertaining to volcanoes, produced by volcanoes.

Vertical, perpendicular, overhead.

Vapor, mist, fog, small particles of water.

Vesicles, small particles or drops.

Verticil, whorled, having leaves or flowers in a circle round the stem.

Volatile, evaporating or flying off easily.

Vascular, made up of vessels, or full of vessels.

Vasiform tissue, is made up of large tubes.

Venation, the arrangement of the ribs or veins in leaves.

Viscid, stringy, sticky, slimy.

Verticillate, whorled.

Verdure, foliage, herbage.

Vibrate, to swing or oscillate.

Vacuum, an empty space, a space from which the air has all been removed.

Vitality, life, the vital or living principle.

Vital functions, those functions or actions which are indispensable to organic life.

Vetches, a liguminous plant allied to the pea, bean, and lentil.

Warping, a process in agriculture similar to irrigation.

Wealden, a fresh water group of rocks, composed of clay, lime marl, &c.

Zigzag, in a crooked direction, forming short angles.

Zenith, that point in the sky or celestial hemisphere which is vertical to the spectator.

Zanthine, a substance found in urinary calculi.

Zeolite, a mineral composed of silica, alumina and lime.

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