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SCIENTIFIC TRACTS,

DESIGNED FOR

INSTRUCTION AND ENTERTAINMENT,

AND ADAPTED TO

SCHOOLS, LYCEUMS, AND FAMILIES.

CONDUCTED BY

JOSIAH HOLBROOK, AND OTHERS.

VOL. I.

BOSTON.

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Corner of Washington and School Streets.

1831.

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DISTRICT OF MASSACHUSETTS, TO WIT:

District Clerk's Office.

BE IT REMEMBERED, That on the seventeenth day of May, A. D. 1830, and in the fiftyfourth year of the Independence of the United States of America, Carter and Hendee, of the said district, have deposited in this office the title of a book, the right whereof they claim as proprietors, in the words following, to wit:

'SCIENTIFIC TRACTS, designed for Instruction and Entertainment, and adapted to Schools, Lyceums, and Families. Conducted by Josiah Holbrook, and others.'

In conformity to the act of the Congress of the United States, entitled, "An Act for the encouragement of learning, by securing the copies of maps, charts and books to the authors and proprietors of such copies during the times therein mentioned;" and also to an act, entitled, "An Act supplementary to an act, entitled, 'An Act for the encouragement of learning, by securing the copies of maps, charts and books to the authors and proprietors of such copies during the times therein mentioned,' and extending the benefits thereof to the arts of designing, engraving and etching historical and other prints."

JNO. W. DAVIS,

Clerk of the District of Massachusetts.

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SCIENTIFIC TRACTS.

NUMBER I.

THE ATMOSPHERE.

PART I.

FEW subjects are more important, or less understood, than the atmosphere we breathe. As it surrounds the earth, and presses with great weight upon its surface, it comes in contact with everything, and bears a most interesting relation to every animal that walks upon the earth, swims in the sea, flies in the air, or creeps in the dust—to every plant that is pleasant to the sight, or good for food—and to every mineral that glitters in its bed, adorns a cabinet, or is used in the arts.

It moves our lungs, circulates in our veins, warms us in our fires, enlivens the midnight lamp, and makes it an agreeable substitute for the light of day, fans us in the breeze, terrifies us in the tornado, conducts sound, now in the soft whisper, the voice of intelligent conversation, the flashes of the orator, or enchanting music, now in the roar of the cannon, the groans of the dying, or terrific thunder; it wafts the ship, heaves the placid ocean into billows, takes the heat of the equator and carries it to the poles, and exchanges it for a cooling breeze, which it kindly returns to temper the scorching rays of the torrid sun; or, using the language of an elegant French writer, 'In the use of the atmosphere, man is the only being who gives it all the modulations of which it is susceptible. With his voice alone, he imitates the hissing, the cries, and the melody of all animals, while he enjoys the gift of speech denied to every other. To air he also sometimes communicates sensibility; he makes it sigh in the pipe, lament in the flute, threaten in the trumpet, and animates to the tone of his passions, even the solid brass, the boxtree, and the reed. In a word, he harnesses it to his car, and obliges it to waft him over the stormy billows of the ocean.'

This faithful servant and constant friend is still neglected. Few appreciate its importance, none understand all its uses. While every breath furnishes us with fresh and *living* proof, that the atmosphere is faithful to its trust, we seldom inquire what agent is constantly moving our lungs, or by whom it was provided and fitted for its office.

How then can we employ an hour more rationally or pleasantly, than in devoting it to this constant companion, and faithful, but neglected friend.

Before we can understand, or at all appreciate the importance and infinitely varied relations of this substance which envelopes our globe, we must learn something of its properties and operations—what are its ingredients, and how it acts.

All the properties and operations of the atmosphere may be classed in two divisions, viz. chemical and mechanical. Weight and elasticity are the properties by which nearly all the mechanical operations are conducted; and although these operations are literally innumerable and highly interesting, they must give place on the present occasion, to its not less numerous or interesting uses and phenomena conducted by chemical agencies.

Among the infinite, and infinitely varied chemical operations, constantly carried on in the processes of nature and the arts, scarcely one can be found, with which the atmosphere has not some connexion and some agency. It must be understood, however, that in much the greatest number of cases, in which the atmosphere acts as a chemical agent, but one portion of it takes any considerable part. And although this portion constitutes but about one fifth of the whole, it fills a greater variety of offices, is more active and more efficient in giving power to other agents, in moving and calming the elements, in preserving order and promoting health and happiness, than almost any other ingredient hitherto discovered in the material universe.

The name of this most efficient and useful part of the atmosphere, this almost universal agent in nature and the arts, this mover and regulator of other agents, and friend of man, is Oxygen.

No substance, unless it is heat, is so universally diffused through the material creation; none so extensive and varied in its forms and combinations; none to which artists are obliged to make such constant application for aid, or so often to consult, or, if not consulted, disappoints them with defeat, as this same oxygen, of which we are speaking. It constitutes not only the most interesting portion of the atmosphere, but more than seven eighths of water, nearly one half of the whole vegetable kingdom, a considerable part of soils and mountains, whatever the ingredients or the strata of rocks which compose them, enters extensively and largely into the ores of metals, and into the rare and precious minerals.

But our subject is the atmosphere, and not water, vegetables, soils, mountains, metals, or rare minerals, however interesting, or worthy of attention. Oxygen, acting in the atmosphere, is the agent whose character we are now examining, the constant companion we are now conversing with, the neglected friend we are now consulting. We must of course inquire what powers this agent possesses, what part it acts in the great theatre of nature; how it gives success to the industry of the artist, and defeats his most unwearied attempts to go counter to its dictates.

To explain fully all the operations carried on by the agency of oxygen, would require volumes instead of a small tract. A few of the most important can therefore be mentioned, which are the following.

I. Oxygen *supports life* by aiding the lungs in the process of respiration.

The lungs inhale air twentysix or twentyseven times in a minute, taking in, at each inspiration, about forty cubic inches, which is something over one hundred hogsheads a day. A chemical action is constantly carried on by the atmosphere and lungs, which the Creator of both has so wisely and wonderfully fitted to each other. By this action, nine or ten gallons of oxygen are consumed in an hour, or taken up by the blood to form another kind of an entirely different character, to be mentioned and explained in another place.

Not only the human race, but the whole animal king-

dom, are constantly using and constantly consuming this vital part of the atmosphere. Fishes can no better live without air, or oxygen, than animals upon land. This oxygen they obtain from air, which is always contained in water in sufficient quantities for their purposes. If air is entirely removed from water by distilling, or the air pump, fishes will live in it but little longer than land animals when shut from the atmosphere. Not only fishes, but insects, and the humblest reptiles creeping in the dust, need a portion of oxygen, which they are constantly consuming.

If any animal be confined in a vessel or tight room, from which the atmosphere is entirely excluded, he may live until the oxygen is so far consumed as to be unfit for respiration, when he will die. Many persons have lost their lives from the want of a supply of this vital air. The most remarkable instance, of such a disaster on record, occurred at Calcutta, in a prison called the 'black hole.' One hundred and fortysix English prisoners were forced into a room eighteen feet square, from which fresh air was almost wholly excluded. Very soon after they entered, a profuse perspiration commenced, followed by a high fever and raging delirium, with cries, 'air, air, water, water,' throwing out insults to their merciless captors, that they might be provoked to put them out of their wretched existence.

They entered this prison of death at eight o'clock in the evening, and at six in the morning, but twentythree from the whole number retained the vestiges of life.

Although oxygen is essential to the support of life, in a pure state it will soon destroy it, by the sudden and powerful excitement it produces in the system. A few inhalations of pure oxygen will increase the pulse from seventy or eighty, to one hundred and twenty, or one hundred and thirty, beats a minute.

Inhaling air with a very little more than the common proportion of oxygen, produces a sudden and remarkable effect on the system. The substance known by the name of exhalating gas, which has a similar effect upon the feelings with ardent spirits, or more like the vapor of spirits, or of ether, differs from the common atmosphere,

only in containing thirtyseven per cent. of oxygen, instead of twentyone per cent.

Aqua-fortis, or nitric acid, is composed of the same ingredients with the atmosphere, and owes its great power in corroding almost every thing it touches, to the seventyfive per cent. of oxygen it contains.

A few drops of this acid would certainly and suddenly destroy life, while the atmosphere is essential to support it.

II. *Oxygen supports combustion.* Every child knows that fire will not burn without air. But some kinds of air will instantly extinguish it. Whenever we see combustion going on, whether in a candle, a common fire, or in the burning of a city, we may know that oxygen is present, and is the principal agent in producing the light, the heat, or the terror. If a burning body be confined in a small portion of atmosphere, it will continue to burn until the oxygen is consumed, when it will go out. Any one may prove this by a simple and useful experiment. Place the small portion of a candle upon a piece of cork or other light body, and let them float upon water in a basin. While the candle is burning, invert a pint or quart glass, so as to enclose it, and entirely exclude the atmosphere. The flame will continue until the oxygen is consumed, when it will be extinguished, and the water rise so as to occupy about one fifth part of the glass, or the portion which was before occupied by oxygen. This experiment illustrates two principles; first, that oxygen is essential to the existence of combustion; and second, that it constitutes about one fifth of the atmosphere.

It is to supply the fire with a greater quantity of oxygen, that the bellows is used. It is to exclude oxygen from burning coals, that they are covered with ashes, to preserve them alive when left. While enough air is admitted to continue the coals in a state of ignition, the quantity is not sufficient to carry on the combustion with any rapidity; consequently the fire is not extinguished, nor the coals consumed.

If pure oxygen be thrown upon a burning body, it instantly increases the power of the combustion. If a candle, just extinguished, be immersed in a vessel containing

this gas unmixed with any other substance, it will be instantly relighted. Many substances will burn in this air in a pure state, which will not in common air. If iron be heated and immersed in pure oxygen, it will instantly melt and burn, throwing its particles in every direction, with an intense and brilliant light. Consequently, if the oxygen of the atmosphere were not diluted or weakened by another kind of air, stoves, andirons, and numerous other instruments made of iron, would melt and be consumed the instant they were raised to a high heat. Almost everything would be combustible, and the earth would soon present one great and general conflagration. How wise and how good, then, is the Creator of the atmosphere, not only in furnishing it with oxygen to support life and combustion, but in diluting it with another substance, to prevent its destroying every living being upon the earth, and the earth itself!

III. *Oxygen carries on fermentation.* Without it, neither cider, beer, wine, or even yeast, or light bread, could be formed. Almost all animal and vegetable substances are liable to ferment, and, consequently, to waste with decay.

Wherever we witness this process, we may know that the same agent is present and employed, as conducts respiration and combustion.

Numerous substances undergo four evident and distinct changes by the power of this agent. These four changes, to which nearly all animal and vegetable matter is liable, may be familiarly and clearly represented and illustrated by one instance of common occurrence, and known to every person. A little reflection will bring to mind four changes the apple undergoes, all of which are produced by oxygen.

The first is giving it a sweet taste, or forming in it a quantity of sugar. This change takes place when apples are bruised, or ground to pomace, for the making of cider. A single apple, if broken into pieces, and exposed to the air, will show this fact. It will soon become sweet, especially if the weather is warm, whatever may be its natural taste. The juice of the apple, when running from the cider press, is always sweet, and contains sugar. This

sugar is formed by the oxygen of the air combining with the substance of the apple.

During this change, no spirit or alcohol is formed, and the liquid is of course useless to the distiller, and can do no injury by spreading intemperance. But if it be exposed to the air until a second portion of oxygen is added, the sugar is destroyed and alcohol formed.

Alcohol, or spirits, whenever it exists, whether in beer, cider, wine, gin, brandy, rum, or any other intoxicating liquor, is formed from sugar.

In the second change, or stage of fermentation, then, sugar is destroyed and alcohol formed. This change is frequently rapid and violent, especially if the liquor be moderately warm, and freely exposed to the atmosphere. When a cask of cider, recently from the press, is placed in a warm situation, and more if it be shaken, so as to bring a great number of particles in contact with the air, a commotion, sometimes violent, arises in the liquid, which is produced wholly by the action of oxygen upon it. If casks be filled with the juice of the apple as soon as it is expressed, and immersed wholly under water, or placed in any other situation so as entirely to exclude the air, the second change will be prevented, and no alcohol formed.

A third portion of oxygen destroys the alcohol, and forms an acid. This change is always more gradual than the second, and sometimes produced with difficulty; though it *partially* takes place, whenever cider, beer, or wine, is exposed for any length of time to a warm atmosphere. The change may be wholly produced in the liquids just named, or in alcohol, in almost any other form, if a large surface be exposed to the air, frequent motion given, and yeast or some other fermenter added.

Not only common vinegar, but most of the stronger acids, are formed by the agency of oxygen. It has already been observed, that it constitutes about three fourths of nitric acid. Sulphuric acid, or oil of vitriol, is formed by burning sulphur in oxygen, or with saltpetre, which contains it in large quantities. Phosphoric acid is formed by burning phosphorus in a similar way.

For a long time it was supposed, that all acids were

formed by this agent, and hence its name, which signifies the former of acids.

The fourth and last change, frequently witnessed in the substance of the apple, is putrefaction. If vinegar be freely exposed for a long time to a warm atmosphere, it becomes putrid. The ultimate or final effect of fermentation, upon all animal and vegetable matter, is, decay, or an entire decomposition.

Notwithstanding every species of matter in the whole animal and vegetable kingdoms, is liable to undergo the four changes above described, certain circumstances will entirely prevent either. These circumstances are, seclusion from the air or moisture, and more than a moderate degree of heat or cold.

By confining the flesh of quadrupeds, of fowls, or of fishes, in tin canisters, perfectly air tight, it is kept for years in a fresh state, without injury.

Fresh animal food has been frequently preserved in this way during a three years' voyage at sea. Any animal or vegetable substance, if made perfectly dry, will undergo no fermentation and no decay. The same is true if kept in a frozen state, or frequently raised to a temperature near boiling heat.

IV. *Oxygen acts upon all the metals.* By this action the rust of iron, the dross of lead, the corrosion of copper, brass, and silver, and the most beautiful paints, such as red and white lead, chrome, yellow and blue vitriol, is produced.

Some of the metals combine with oxygen rapidly, others gradually, or even with difficulty. Iron, for example, is very liable to rust, or oxidate, as chemists say; while gold utterly refuses to combine with oxygen, as it does with most other substances, except by an indirect process. If lead be kept in a melted state for a short time, it absorbs so much oxygen as to be changed wholly into dross, which is an oxide lead. But gold may be kept in a state of fusion and motion for months, or years, and never admit a particle of oxygen into its connexion; so proud a substance as gold, may, however, by an indirect process, be led to combine with oxygen, and after that with many other substances. When oxygen once gets

in possession of this metal, it readily transfers it to the surfaces of numerous substances, and extends it over a greater space than can be done by beating or any other process. By the aid of this agent, then, numerous utensils, and even cloth, cords, and thread, are gilded at a most trifling expense.

Not only paints, but dyes are prepared, and attached to the surfaces or fabrics to which they are to be applied by this general agent. Without its aid in giving permanency to colors, most dyes are mere stains, and entirely removed at the first washing. Some colors it heightens or deepens after they are applied. Ink of a good quality, is sometimes pale, when first applied to paper, but after a few days, it becomes of a deep and permanent black. Indigo, when first formed from the plant, is green, as it is when first applied to cloth; but by a short exposure to the air, or to oxygen, it becomes the beautiful and permanent blue so extensively witnessed in woollen, silk, and cotton goods. Oxygen is not only the most active and general agent in preparing colors and fixing them to their fabrics, but it is more generally and successfully employed than any other, for destroying them. The important process of bleaching is conducted by it, whether by the old method of exposing cloth alternately to moisture and the sun, or by the modern and improved method of immersing it in chlorine.

It seems, then, that this remarkable character not only fills numerous and important offices, but those of almost an opposite nature, and that it possesses properties, which are not only distinct, but opposite.

Though oxygen is by far the most active and general agent in conducting the innumerable chemical operations of the atmosphere, another ingredient is the most abundant. It has already been observed, that only one fifth, or, more exactly, twentyone per cent., of the atmosphere is oxygen. The other essential ingredient is *nitrogen*, which constitutes seventynine parts in a hundred. This ingredient, though abundant, is almost wholly inactive. Its properties appear to be entirely of a negative character. It neither sustains nor destroys life nor combustion. It neither carries on, nor retards, fermentation in any of

its stages. It does not act upon metals, nor interrupt the action of its associate upon them. It takes no part in the preparation or the application of paints or dyes, nor in destroying them when formed. It neither aids the chemist, the mechanic, the housekeeper, nor the farmer, nor interferes with any of their operations. It has no agency in forming sugar, wine, cider, beer, bread, or acids, nor in corroding metals, or spreading intemperance by intoxicating liquors.

Although the properties of nitrogen are almost wholly negative, and it appears to be little more than an idle spectator to the endless variety of phenomena produced by the atmosphere, it is still an essential, as well as the most abundant portion of it. Without it, the air which surrounds our globe, could not conduct those innumerable, constant, but silent operations, with the sole design of promoting the health and happiness of the innumerable living and active beings it envelopes.

The most important office which nitrogen fills in the great theatre in which it moves, appears to be occupying the space which might otherwise be occupied by its more powerful colleague; to dilute or weaken oxygen, which, if it occupied the whole region of the atmosphere, would possess so much power as to defeat the numerous objects so wisely designed by its creation to accomplish.

While it never interferes with the vital action of oxygen upon the lungs, it occupies the greatest part of their contents, and by that means prevents the violence and consequent destruction which must be produced, if the large contents of those organs were wholly occupied by the more powerful ingredient in the atmosphere. While it never interrupts the beautiful and useful phenomenon of combustion in its gentler forms, as in the useful and domestic arts, it prevents the vast heap of ruins the earth must soon present, by a general conflagration, if it was enveloped in an atmosphere of pure oxygen.

Not only in the extensive and constant operations of respiration and combustion, but in fermentation, the oxidation of metals, and the minor offices of the atmosphere, it appears to be the use of nitrogen, to prevent violence, and to render the innumerable and endless movements in

this vast theatre of nature, gentle, uniform, and constant, at the same time, that it does not destroy or impair the power of the agent which conducts them.

This abundant and harmless portion of the atmosphere does not, like its more enterprising neighbor, infuse itself into nearly every mass of matter in the three great kingdoms of nature, but, besides forming more than four fifths of the aerial ocean which surrounds the earth, it constitutes a considerable part of all animal substances, though less than oxygen.

It is not found, in any quantities, either in the vegetable or mineral kingdom, of both of which oxygen constitutes a large part.

Chemists have generally considered the two substances already spoken of, as the essential ingredients of the atmosphere. Several others are, however, always found in it, and if they are not concerned in its more important operations, they fill many minor offices in contributing to the endless and constant wants of the innumerable beings living and acting upon the earth.

Such is carbonic acid, or fixed air. This gas, which is nearly twice as heavy as common air, is found to exist, at all times, in every region of the atmosphere, from the lowest ravine or cave, to the top of the highest mountain. Except in caves, wells, and some other low places, where carbonic acid settles from its great weight, it is never found in the atmosphere except in small quantities, some say a hundredth part, some a thousandth, but probably variable, existing in larger quantities, at some times, and in some places, than others.

Although this substance is fortunately never found in the atmosphere except in small quantities, it frequently takes an important part in promoting the happiness, and producing the disasters of mankind. It is supposed to be an important agent in the process of vegetation; vegetables having the power of extracting it from the air and converting it to their own sustenance and growth. While the whole animal kingdom are constantly inhaling or consuming oxygen, and at the same time throwing off carbonic acid, the vegetable kingdom are inhaling or absorbing carbonic acid, and, a part of the time at least.

are throwing off oxygen. So that these two great kingdoms of nature are mutually and constantly performing these kind offices to promote the growth and prosperity of each, while they prevent the destruction of both, and of every living existence which animates, enriches, and dignifies this lower creation. For carbonic acid is not only essential to the growth of vegetables, but is certainly and instantly fatal to animals, one full inhalation of which produces death, unless a supply of oxygen is instantly provided. The moment a person enters an atmosphere of this gas, as has frequently occurred in wells, and the fermenting vats of breweries and distilleries, he drops lifeless, and past recovering, except the supply of vital air is immediate.

Carbonic acid is no less fatal to combustion than to animal life. If a burning candle or coal be immersed in it, every appearance of combustion is instantly destroyed ; but it may be again relighted, by letting it into a vessel filled with pure oxygen.

The sparkling appearance and agreeable taste of the best cider, beer, wine, and soda water, are produced by this active substance. By the loss of it, they become dead, as we say, and are not only unpleasant to the taste, but injurious to health. So that the same substance which is distressing and fatal if taken into the lungs, gratifies the taste and promotes health when received by the stomach.

By three classes of operations in nature and the arts, carbonic acid is constantly formed, and oxygen destroyed. These are respiration, combustion, and fermentation. It has already been remarked, that the whole animal kingdom are constantly consuming oxygen ; they are also forming carbonic acid. The same double result is produced in most instances of combustion, and in every instance of fermentation, in all its stages. It seems, then, that the vital principle of the atmosphere is constantly destroyed in vast quantities, and that a substance instantly fatal, both to life and combustion, is constantly forming, and yet the atmosphere continues to answer the great purpose for which it was designed, and without a sensible change in its character.

Chemists have not yet discovered any other process, by which this uniform and healthful state of the atmosphere is preserved, but the reciprocal and mutual action of the animal and vegetable kingdoms; the former, as has already been observed, by constantly consuming oxygen and producing carbonic acid, the latter by taking up this substance so fatal to life, and giving in exchange the ingredient which supports it.

What a striking instance is this, of economy displayed by the great Architect of the universe, in the work of his material creation, and how much more striking and wonderful is its fitness to answer the purposes—to promote the ceaseless advancement of his intellectual and moral creation, which constitutes the worth, the dignity, and happiness of his boundless dominions.

Carbonic acid is not only found in small quantities in every part of the atmosphere, but is extensively diffused through the mineral kingdom, especially in quarries and mountains of limestone, every particle of which contains a portion of it safely laid up for the use of the chemist and artist, whenever he needs its use, or wishes to prove its existence.

Besides the air last mentioned as existing in the atmosphere at all times and in all places, several others are occasionally found, and in some places they are constantly forming in great abundance, among which is one resembling the gas used for lighting cities.

This gas is produced in large quantities in marshes, masses of stagnant water, and in large cities, where a due regard to cleanliness is not observed; and is the cause of sickness, and perhaps of malignant fevers. By moving the earth in the bed of any pond, and even in most streams of water, bubbles will be disengaged, and rise to the surface, where they may be collected in bottles, and by applying a lighted candle, they will be found to be combustible.

It is much lighter than common air, and consequently rises into the higher regions of the atmosphere, where it is frequently exploded by electricity, and is perhaps the cause of shooting stars sometimes observed in the heavens.

The properties and operations of the atmosphere already mentioned, belong more to the several ingredients which compose it, than to the whole substance as a mass. It however possesses some properties, and performs many great and important operations, in which it is to be viewed as one body. For example, every particle of the atmosphere, even in the driest places and seasons, contains a portion of moisture. By the power of absorbing and retaining this substance, it performs a most extensive and important service, in producing action, and preserving order, health, and life, in moving and living beings. It is constantly relieving the earth, and the numerous bodies upon its surface, from their superfluous moisture. It raises from the ocean, by the silent process of *evaporation*, as much water as flows into it, by the Amazon, the Mississippi, the Danube, the Ganges, the Nile, and all other rivers which it receives into its bosom. Experiments have proved that during twelve hours of a summer's day, about twenty-five hogsheads are evaporated from an acre, or sixteen thousand hogsheads from a square mile. The water thus taken from the earth, and diffused through the atmosphere, is again collected in clouds, and when the air can no longer sustain their weight, they fall in the form of rain, hail, or snow, and after enlivening the face of nature, or passing into the ocean, the same vehicle which before conducted it through this round of services, again takes it up to repeat the process.

Not only in relieving the earth from its superfluous moisture, and in preparing materials for refreshing showers, as well as the raging storm, but evaporation is a most important and essential process for the chemist in forming his salts and powders, for the farmer in preserving his hay, and for the mechanic and housekeeper in their endless and nameless operations, for preparing the comforts and the luxuries of civilized and refined society. Besides going this round of ceremonies with water, in taking it from the earth, in diffusing it far and wide, and again collecting it in clouds, and returning it to refresh the living creation, and to replenish rivers and the ocean; the atmosphere transports it, while in clouds or vapor, from continent to continent, that it may give to the in-

habitants living upon the four quarters of the globe, a portion of its genial influence.

Every particle of the atmosphere contains a portion of heat as well as moisture. To this substance, no less than to water, it is the general and all powerful vehicle. It is constantly transporting heat from the equator to the poles, from land to sea, and from sea to land, from the valley to the mountain, and from hill to hill. By this office, performed by the air in these great operations of nature, the heat upon the earth is in a measure equalized. The deficiency in one country is supplied from the excess of another. The intense cold of one climate is softened by tempering the scorching heat of another; and by the equilibrium thus produced, both are rendered productive of more life and more happiness.

The connexion of the atmosphere with heat is the source of every current and motion it receives, from the gentle breeze to the raging hurricane. The theory and the different kinds of winds, all of which are nothing more nor less than the atmosphere in motion, and all produced by the same cause, might seem to deserve a full explanation in this place. But from the space allotted to the present number, this subject must be deferred to another. It is difficult in this connexion, however, to avoid the remark, that the expansibility of the atmosphere by heat, and its compressibility by cold and pressure, are among its most remarkable and important features, and distinguishes this and other airs from matter of every kind, either in a solid or liquid state. Air of every kind appears to be capable of expansion and compression to an indefinite degree. This property belongs to each gas separate, and to several combined.

In the manufactory of soda water, one hundred and thirty gallons of carbonic acid is forced, by the means of a condensing pump, into a cask, of the contents of ten gallons, six of which are occupied by water. In the fine syringe, the atmosphere is suddenly compressed into so small a space, as to cause the oxygen it contains to ignite a piece of cotton, previously prepared by moistening it with water highly charged with saltpetre, and then thoroughly dried. When ninety-nine hundredths of the

air contained in a receiver, is removed by an air pump, the remaining one hundredth is immediately expanded so as to occupy the space which was before occupied by the whole. If a common Florence flask, while containing nothing but air, be heated to a high degree, and then the mouth immersed in water while it is suffered to cool, the water will rise to occupy almost the whole contents of the flask.

Familiar examples might be adduced, almost without number, to show the great capability airs possess, of being expanded and compressed to an unlimited degree.

And every kind of air possesses this property at all temperatures. In this respect, gas differs from vapor, which in other respects resemble each other. All vapors, whether produced from liquids or solids, are, like air, highly elastic, and capable of great expansion and compression. But by lowering the temperature to which they are exposed, the vapor again becomes a liquid, or solid, when it loses its elasticity, and its compressibility. While air retains both at all temperatures, and in all situations.

This peculiar and highly interesting property of all gases, gives to the atmosphere some of its most important powers and uses. It is evidently essential to the existence of winds, and to every motion of the air, unless it may be in a slight degree. It is from this property, that the atmosphere so readily gives place to all other substances passing through it. Were it not for this, we should be met with a powerful resistance, whenever we attempted to move from place to place. This is the origin of the trade winds, occupying about sixty degrees of the equatorial regions of the earth, blowing constantly from east to west, of the monsoons blowing six months of the year in one direction, and the other six months directly opposite, of the deadly simoom, of land and sea breezes, of the most variable and shortest currents of air, of the gentle breeze, the brisk gale, the raging tempest, the sweeping hurricane, the water spout, and the tornado. It is by the great expansion and compression of air, that ships are constantly moving from continent

to continent, that the noxious vapors of cities are removed to give place to an atmosphere more fresh and pure, and that it constantly preserves, amidst all the contaminating influences to which it is exposed, its salubrious and vital energies.

In a general view of the properties, powers, and uses of the atmosphere, of the essential ingredients which compose it, and the various other substances it absorbs and wafts in its currents, the numerous odors constantly meeting us, ought not to be overlooked. This class of bodies is almost infinite in variety, which are divided into atoms so minute, that the fragrance of a flower diffuses its agreeable odor into every particle of atmosphere, to a great extent around it, and by this, adds to the beauty and sprightfulness, the sweetness of spring.

Such is the power of the atmosphere, and the great divisibility of matter, that it sometimes takes up, and carries from place to place, substances of the greatest density. Even the heaviest metals, such as gold and platina, are capable of being reduced to so fine a powder, as to be supported in the atmosphere, and inhaled by the lungs.

The limits to which we are confined in our view of a subject so vast and so various in its applications and uses, as the ocean of air which envelopes our globe, have required us to be brief. In many cases we have been permitted merely to hint at a subject, whose importance seemed to require a large expansion. In none have we been able to make that full, minute, and varied application to practical and common concerns, and especially to the moral developement, which give to science its greatest utility, interest, and sublimity. Partially to answer these important purposes, to which every science and every kind of knowledge ought to be applied, this tract will be closed by a few questions relating to the subjects presented in the preceding pages.

1. Has the atmosphere received greater or less attention in systems of instruction than its importance deserves?

2. Has a knowledge of the ingredients and properties

of the atmosphere, or has it not, a relation to life and health ?

3. What vital process in the animal kingdom is conducted by the atmosphere ?

4. How many times do persons commonly respire in a minute ?

5. About how much air is received into the lungs at each inhalation ?

6. Which ingredient in the atmosphere is most abundant, oxygen or nitrogen ?

7. Which of the two essential ingredients in common air is most active ?

8. If a person be deprived of oxygen, how will he be affected ?

9. Which substance is essential to combustion, oxygen, or nitrogen ?

10. Does carbonic acid promote or destroy combustion ?

11. Why does the bellows hasten combustion ?

12. Why is fire preserved by covering it with ashes ?

13. Which ingredient in the atmosphere conducts the process of fermentation ?

14. How many changes does vegetable matter undergo by the process of fermentation ?

15. What substance is produced by the first change, acid or sugar ?

16. During which change is alcohol formed, the second or fourth ?

17. In what does fermentation, if continued, always result ?

18. Which change is most rapid, the second or third ?

19. How should liquids undergoing the second change be treated, excluded from the air, or exposed to it ?

20. When a liquid is undergoing the third change, or forming into vinegar, does the fermentation need retarding or hastening ? should it be excluded from the air or exposed to it ? frequently moved or remain at rest ?

21. Which portion of the air has the agency in corroding metals, and producing rust, also paints, oxygen, or nitrogen ?

22. Which metal most readily combines with oxygen, gold or iron ?

23. What is the chemical name of the rust of iron ? also of the dross of lead ?

24. Why does covering the surface of metals, such as iron or brass, with varnish or oil, prevent their corroding ?

25. Of what substance upon the surface of the earth, except air, does oxygen constitute a part ?

26. Which is most abundant in the vegetable kingdom, oxygen or nitrogen ?

27. Where is nitrogen most abundant, in animal or vegetable matter ?

28. If the atmosphere were pure oxygen, would it be more or less favorable to respiration and combustion ?

29. What appears to be the principal use of nitrogen in the atmosphere ?

30. How is the animal system affected by inhaling pure oxygen ?

31. How is animal life affected, if full inhalations of carbonic acid be taken into the lungs ?

32. Do the lungs throw off more or less oxygen than they receive ?

33. Do they throw off more or less carbonic acid than they receive ?

34. What other operations in nature, except respiration, produce carbonic acid ?

35. What substance which is fatal to life, is thrown off by burning charcoal ?

36. Is the carbonic acid in cider, beer, and soda water, favorable, or unfavorable to health ?

37. What natural agents are employed in evaporation ?

38. What finally becomes of the moisture taken up and carried off by the atmosphere ?

39. What becomes of the water which falls into the ocean, through the medium of rivers, rain, &c.

40. Which is most compressible, air or water ?

41. Does heat expand, or contract air ?

42. What is the most powerful vehicle in nature, for transporting heat and moisture ?

43. What is the cause of winds, and all motions of the atmosphere ?

44. In what part of the earth, and over how great a space, does the wind blow in one direction through the year ?

45. Is the action of the atmosphere upon combustion, a chemical or mechanical process ?

46. Is the oxidation of metals a chemical or mechanical operation ?

47. Is the weight of the atmosphere a chemical or mechanical property ?

48. In how many divisions may all the properties and operations of the atmosphere be classed ?

49. Is the elasticity of air a chemical or mechanical property ?

50. What is the principal agent in the process of bleaching ?

51. What acid is composed of three parts of oxygen, and one of nitrogen, nitric, or sulphuric ?

52. If sulphur be burned in oxygen gas, what acid is the result, sulphuric, or muriatic ?

53. How is phosphoric acid formed ?

54. What part of the vegetable kingdom is oxygen ?

55. Of what minerals does oxygen constitute a part ?

56. Is any substance more universally diffused through the material creation than oxygen, and what ?

REMARKS.

THIS pamphlet is the first number of a series of 'tracts,' designed as instruments for operating in the great and common cause of Popular Education. They are intended to be brought within the comprehension, and to meet the wants of the great *mass* of the community; especially of the *industrious classes*, who have neither time nor opportunities to devote their lives to intellectual pursuits. It is hoped they will prove to be worthy and agreeable companions in every family circle, and that they will take some part in their *conversation*, and if so, that they will enliven, extend, and ennoble, this seat and source of individual and national character and happiness.

Endeavors will be made to render these sheets welcome visitors to schools, by carrying to them useful and entertaining knowledge, and in a measure to relieve those

active, sprightly, intellectual, little beings, which compose them, from the *dull monotony* of common school exercises.

They are also intended to furnish profitable subjects for the exercises of Lyceums, which may be introduced, explained, and enlarged upon, in a *familiar* way, by those who may undertake to instruct and entertain these *social* assemblies.

It is hoped they may be found agreeable companions, at public places of resort, such as public houses, steam-boats, reading rooms, &c.

To answer the objects above proposed, it will be the earnest desire of those who conduct them, to give them the following features.

1. To have them contain *useful knowledge*, in the strictest sense of the word. They will deal more with *facts* than theories; more with *settled principles*, than doubtful speculations; more with *common* than rare things; more with objects *around us*, than those which may or may not exist in distant parts of creation; more with the *application* of the well known properties of the materials our Creator has put into our hands, and the principles he has established to fit them for our use, than to establish some favorite doctrine in a system of metaphysics.

2. They will be familiar. Technicalities and labored verbiage will as far as possible be avoided. Attempts will be made to present *things, properties, principles, applications*, in the simplicity of nature, and not through labyrinths of terms, and mazes of declarations.

3. They will be practical. Whatever may be the subjects introduced, whether the physical sciences, natural history, mathematics, political economy, agriculture, the mechanic arts, biography, or history, they will have a practical bearing upon common life and common interests.

4. They will be moral. It will be the constant aim to awaken and elevate moral sentiment, and to present everything as the gift, or under the direction of a great and wise Creator, and a constant and boundless Benefactor.

APPARATUS

FOR

SCHOOLS, LYCEUMS AND ACADEMIES.

The *economy*, no less than the general utility, of visible illustrations, is now universally acknowledged. It has had the unanimous assent, so far as known, in not less than fifty conventions of teachers, at which were present more than ten thousand persons. Apparatus is more economical than books, because one instrument is sufficient for a *school*, instead of an individual—because it is more *durable*—because impressions received through the *eye*, especially by *young minds*, are more *clear*, more *rapid*, more *permanent*, more *agreeable*, and, of course, more *efficient*, than those through the ear.

The change already effected in Schools, by the geometrical diagrams and solids, is unparalleled. By them the simple elements of Geometry, from an abstruse study in a collegiate course, have become the most agreeable, as well as the most useful branch in Infant Schools, and to a great extent in Common Schools.

A manual, and three sheets of diagrams, one of which contains the manuscript letters, can be used without the solids, either in Schools or families. The price of the four articles is \$0,50; that of the whole of the geometricals is \$4. A set of common school apparatus, embracing the geometricals, one or two instruments for Arithmetic, several for Geography, and a few for Astronomy, is \$10. For Lyceums and Academies, philosophicals are \$15; orrery, \$6; tide dial, \$4; seasons, \$2; whole of the astronomicals, \$15; a convenient chemical set, \$25.

As some counterfeit apparatus has been made, of a defective character, and offered for sale under Mr. Holbrook's name, and a few individuals imposed upon, purchasers will do well to be cautious of whom they procure it. None but that made under Mr. Holbrook's direction can be used with books which are prepared and preparing to illustrate and apply it.

CARTER, HENDEE AND BABCOCK have the apparatus above-named for sale, with a large assortment of Books, designed for INFANT and PRIMARY SCHOOLS, for LYCEUMS, ACADEMIES and elementary and practical instruction generally.

SCIENTIFIC TRACTS.

NUMBER II.

GEOLOGY.

PART I.

GEOLOGY is a modern science. It is but little more than a quarter of a century since it received its existence, especially in our own country. Before that, it was neither understood, nor mentioned in our highest institutions of learning. Our most learned professors possessed no practical knowledge of this subject, nor did our country contain any source from which it could be obtained. They were unable to recognise or name the most common mineral in the streets. Indeed, most of the knowledge in Europe upon this subject, was drawn from conjecture, rather than facts.

Within a few years past, however, Geology has made greater progress than was ever made by any other science in the same length of time. From being wholly unknown in our colleges, it has become a familiar and delightful subject in Infant Schools. Thousands of children under ten years of age, are now better practical Geologists, than any individual who could be found in the country thirty years ago. They have not collected their knowledge from their school-rooms or their books, but from actual observation, and examination. They are acquainted with a certain rock or mineral from seeing it, and know its situation, by breaking it from the mass to which it was attached. Their school-rooms and their parlors bear infallible testimony both of their knowledge and their industry. Their countenances testify that their collections are the price of blows upon the rocks, rather than upon their backs. Stripes did not compel them to obtain their knowledge, but their knowledge

induced them to put on the stripes. Their exercises to obtain it were permitted, not compelled. Their subject is understood rather than committed, known rather than imagined.

The progress of this subject has not only been unparalleled as a science, but its application to Agriculture, to Civil Engineering, and to many of the arts, has already added to the wealth of our country, to a vast amount. It has brought to view some of the finest specimens of marble upon the earth, which had been used by farmers for common enclosures for one hundred and fifty years without being known. It has discovered valuable quarries of building materials, within a few rods of walls which were brought from a distance of as many miles. It has discovered the material from which coperas is made, and led to the art of manufacturing it in such perfection, and at so cheap a rate, as to put an end to the importation of that article so indispensable, and so extensively used in the arts. It has brought to view inexhaustible deposits of the material for the manufactory of the beautiful pigment under the name of chrome yellow, and has reduced the price of that useful substance, from sixteen dollars to fifty cents a pound. It has led to the establishment of a manufactory of epsom salts, where seven or eight hundred tons are made in a year, and of a better quality than can be procured from any establishment across the Atlantic. The numerous and abundant sources of industry and of wealth which it has opened to our country, have increased the treasures of wealth, no less than those of knowledge; the lovers of science and of filthy lucre, have in one instance been gratified by drinking at the same fountain.

If there are yet those who need to ask what is the object of this practical, interesting and sublime science, they can be informed that it means a *description of the earth*; and is hence nearly allied to geography. Both sciences have not however the same province. They do not describe the earth in the same points. Geography, not only describes the great divisions and natural features of the earth, but the political and civil divisions,

together with the changes and improvements made upon its surface by the hands of men. It not only gives an account of oceans, continents, islands and mountains, but of towns, republics, kingdoms and empires.

It is not the object of Geology to give the number, names or situation of continents, islands, or mountains, but of the ingredients of which they are composed, and of the position and arrangement in which they are placed. It takes no notice of the changes which have been produced upon the earth by the industry or the ravages of men, but describes the more sublime changes it has suffered, by the agency of earthquakes and volcanoes; and by the gradual but irresistible hand of time.

The object of Geology is to give us a history, not of the inhabitants which have risen and fallen upon the earth, but of the earth itself. It describes its original formation and present structure, with the gradual and tremendous changes it has undergone, since it came from the hand of its Maker.

It must be acknowledged that our means of information upon this subject are comparatively scanty. Neither history, nor the present appearance of the earth, informs us with any degree of minuteness, what was its state, when 'it was without form and void,' or how great or general were its changes, when the 'windows of heaven opened, and the fountains of the great deep broken up.' Nor can we penetrate beyond a few feet into the bowels of the earth, to ascertain what are its hidden treasures, or the order in which they are stored. Neither the ledges of mountains, the channels of rivers, ravines, caves, wells or any other excavation, either natural or artificial, give us any opportunity to examine the materials, structure or arrangement of our globe, but a few feet below its surface.

Although most of the incidents in the history of our planet, which curiosity, ever upon the alert, would fain unfold, are surrounded and deeply buried in the gloom of ignorance, a few of these incidents are still within our reach, and are too interesting and too important to be withheld from any one who has a heart to feel, or a mind to perceive. A few facts, which can be well established,

upon a subject so important as the creation and history of a planet, and of that on which we ourselves are placed, though but a speck in creation, can hardly fail to light up the curiosity of any mind, which has a spark remaining. To state these facts, as they are learned from history and observation, is the principal object of the present number.

CHAOTIC OCEAN.

The first well established fact worthy of notice respecting the history of our planet, is that there was a time when it was one vast ocean; without a continent, an island, a mountain, a rock, a metal, or a particle of solid matter upon its surface. It contained, indeed, the elements of all solid substances, which now appear so beautiful, so rich, and so various upon its surface; but they were in a liquid state—they were dissolved by heat or water, or more probably by both.

Whatever might have been the agent or agents, which dissolved and held in solution the rocks, islands, mountains and continents, now so firm and so lofty upon our globe, the fact is denied or doubted by no one, who has resorted for information to either of the two great volumes, the book of nature, or the book of revelation. The sublime and interesting account found in the first chapter of Genesis of the creation of our earth, is grounded upon the fact, that it was once a vast and general ocean. Such it must have been when it was without form and void, and darkness was upon the face of the *deep*, and the spirit of God moved upon the face of the *waters*, and commanded *dry land* to *appear*. These statements imply, with a clearness little short of a direct declaration, that there was a time, when our earth was a vast deep—one great body of water—when dry land had not appeared.

This interesting fact, so clearly implied in the book of revelation, is fully corroborated in the older volume, the book of nature. The ocean now holding in solution many, perhaps most of the ingredients which constitute the solid and rocky masses—volcanoes which dissolve the body of mountains and pour them from their

heights in a liquid form, so as to lay in ruins the fairest plains and cities below, — ledges beautifully studded with crystals, and mountains intersected by seams of copper, tin, silver and gold, bear constant and infallible testimony, not merely to the possibility, but the certainty, that the most solid substances were once in a state of solution, and that our planet has been shaken to its centre by the war of its elements.

CONSTANT CHANGES.

History of the past, and observation of the present, unite their testimony to the fact, that the changes the earth has undergone since it came from the hand of its Maker, have been constant, and to a great extent gradual. Whatever construction shall be put upon the word day, as used in the only history we have of the creation of our earth, or however great might have been the changes it suffered during the six days there mentioned, no one can deny or doubt, that great and constant changes have taken place upon its surface since the period there referred to. The changes to which it is daily subject at the present time, must be visible to the most careless observer. The gradual but powerful and irresistible hand of time, even in the short space of 'threescore years and ten,' sometimes gives to extensive districts a new aspect and a new character. In many situations, rocks are constantly forming, in others they are in a state of decomposition; in one case the land is daily encroaching upon the sea, in another, it is carried into the ocean, and gives place to a bay or harbor. Volcanoes are pouring forth from the depths of mountains melted lava, which by a sluggish but a powerful and awful momentum, carry destruction in their course, and bury flourishing cities in ruins, giving no warning to their inhabitants to flee from their danger. While in one case mountains are throwing from their summits their own contents into the valleys beneath, in another the ocean is throwing up islands from its depths. In some instances, islands have arisen out of the sea in a night.

ORDER OF CREATION.

The general order of time in which the earth with its furniture and its inhabitants came to its present form, is sufficiently manifest from the only authentic history we have of its creation, from reason, and from observation. The first step which was taken to change the original chaos into a convenient dwelling-place for living, acting, and intelligent beings, was the formation of dry land. That was necessary to provide for the accommodation of animal and vegetable life. When provision was made for the existence and support of the vegetable kingdom, 'the earth brought forth grass and herb yielding seed after their kind, and the tree yielding fruit after his kind, whose seed was in itself after his kind.'

The creation, and continued production of the vegetable kingdom, made provision for the animal. Then the earth brought forth cattle that walk upon the earth, fowls that fly in the firmament of heaven, reptiles that creep in the dust, and fishes that move in the waters; and each after his kind.

But the tenant for whom the earth, with all its productions of animal and vegetable life, and so richly provided with furniture of a thousand kinds, was not yet created. His creation was to close this august work of the great Architect of the universe. Man was not formed and placed upon the earth, until the earth was fitted for his reception, his convenience, and his happiness—until two great lights were formed, one to rule the day, and the other to rule the night, and the stars also—until the waters which were under the firmament were divided from those above the firmament, and gathered together in one place, and dry land appeared—until grass, herbs, and trees yielded seed and fruit after their kind, and cattle, the fowls of heaven, every creeping thing, and every living creature which moves in the waters, were formed, and made to produce others after their kind, and put in subjection to the lord of this lower creation.

Such is the general order in the work of creation, as

learned from the Bible, from reason and from observation; and yet we have the strongest evidence, that this order was not strictly and minutely pursued through the whole process of bringing the earth into the state in which it is now presented to our view. The whole of the mineral kingdom, all rocks and metals, soils and mountains, were not completed before the creation of the vegetable and animal kingdoms were commenced. So far from it, rocks, soils, and metals, are daily forming at the present time. In many instances, vegetables and animals are deposited in solid rocks far below the surface of the earth. Nay, whole mountains of a great height, and hundreds of miles in extent, are composed of little else than the relics of animals. The greater part of these animals were evidently different kinds of shell fish. But fishes, of the kind that swim, are also found inclosed in solid rocks. In one instance, the relics of one fish were found in the mouth of another, apparently in the act of struggling for his freedom, when both captive and captor were suddenly arrested, and confined, where they closed their struggles and their lives together; and were afterwards converted into stone. In another instance, one hundred and sixteen different kinds of fish were found petrified within a short distance. It has been remarked, that fishes had probably met in general assembly, and were taken when in the act of legislating.

In excavating the section of the Erie canal at Lockport, after descending twenty feet into solid rock, several rattlesnakes were found with the whole form, though in the state of stone, almost precisely retained. At the same place and nearly the same depth, a toad was taken from the solid rock, which when found was in a torpid state, which he had retained perhaps for thousands of years, but when exposed to air and heat soon gave indications of life, and after a short time gained strength enough to hop, but after a few hops closed his existence forever.

Not many years since, in the vicinity of Paris, there was found imbedded in solid rock, and forty feet below its surface, a board several feet long and eight or nine inches wide. At the same place a hammer was found,

the handle of which, with the board was petrified, but the hammer being of iron, retained its natural state.

These are a few instances, among thousands, which might be mentioned, to prove that the changes our earth has undergone, have been gradual and constant, and that minerals, rocks and soils, and even mountains have been formed since the creation both of the vegetable and animal kingdoms commenced, and even after man was formed, and had made some advances in the arts of civilization. Indeed no one can doubt for a moment, who has paid the least attention to the subject, that our globe has been subject to constant and important changes from the time that the materials of which it is composed were formed out of nothing, until the present moment. And these changes which come within our knowledge are so great, as to afford strong evidence that the earth could not have existed for a much longer period than that assigned by Moses.

AGES OF ROCKS.

From views and facts already presented, it must be concluded that rocks and mountains have different ages. Some have existed for six thousand years, while others are at this moment in a process of formation. And there is good reason to believe, that every moment during the whole of this period, these formations have been going on.

We not only know that rocks have different ages, but we know which are oldest. All geologists unite in the opinion, that granite was the first solid substance formed from the great chaotic ocean; and that the coarsest masses of this rock are older than those of a finer texture.

Next in age to granite, is gneiss, consisting of the same ingredients, but of a finer texture and a more slaty character.

Mica slate is considered by most geologists as the third rock in age.

Lime has been forming in all ages of the world. Some deposits of limestone are older than the most recent granito, while others are forming at the present moment. The oldest specimens are coarse and of a

crystalline structure; the most recent is fine or compact in its texture, and destitute of every appearance of crystalization. A bed of the most ancient limestone is found in Bolton, Massachusetts. In the western part of New York, deposits of the same rock are constantly forming at the present time.

ELEMENTS OF ROCKS.

Notwithstanding the rich and endless variety in the external appearance of rocks, their elements are few and simple; and this apparent and beautiful variety is owing more to the proportion and arrangement of the ingredients which compose them, than to their number or variety.

Nine simple minerals have been supposed, by many geologists, to be the elementary substances of which all rocks are composed. And it is well known, that four or five of these, constitute by far the greatest part of rocky and mountain masses, and that more than half both of rocks and soils, are formed from two of them.

The names of these simple minerals, sometimes called the geological alphabet, are quartz, felspar, mica, hornblende, lime, argillite, (common slate,) gypsum, talc, and chlorite. The two first are the most common and most abundant materials which compose the solid mass of our earth. Of the highest and most extensive mountains upon our globe, they are the principal, and to some extent, the only ingredients. They are also, the essential elements of soils, and upon the proper mixture of quartz and felspar, or of silex and alumine, (sand and clay,) the ultimate principles found in these two minerals, the fertility of soils depends.

These two abundant and important minerals in many instances, very nearly resemble each other, though a little experience will enable any one to distinguish them. Quartz is harder than felspar, and much more various in its appearance. It is of every shade of color from nearly black to milk white. The white pebbles so common in the streets and by the way-side, frequently known by the name of flint-stone, are a common species of quartz. Gun-flint is another. Sometimes it is

transparent and perfectly crystalized, when it is improperly called diamond. Diamond rocks and hills are known in many towns in almost every section of our country. The diamond is found but in two or three places upon the earth.

Crystalized quartz is sometimes of a purple color, when it is called amethyst. Jasper, carnelian, calcedony, opal, and several other precious stones, are ranked in the family of quartz.

Felspar is generally white or of a light color, sometimes yellowish, light red, or green, seldom of a dark color. Its fracture differs from that of quartz, as it breaks in small even surfaces or plates, somewhat resembling steps. A strong light thrown upon a recent fracture, gives it a peculiar indescribable lustre, by which it can always be distinguished from quartz.

The two minerals are not only useful as constituting the greater part of soils, rocks, and mountains, but for an important purpose to which each is applied in the arts. Quartz is the essential, and almost only ingredient used in the manufactory of glass, whether for windows, decanters, tumblers, bottles, or any other purpose. Felspar is always used in the manufactory of porcelain or china ware. The substance known by the name of kaolin, or porcelain clay, used both in China and this country in the manufactory of porcelain, is decomposed felspar.

Mica, frequently but improperly called isinglass, is extensively associated with the two simple minerals already described in the structure of rocks. This mineral is sometimes found in plates two feet in diameter, but much more commonly in fine scales but little larger than the head of a pin. It is commonly white, but sometimes black, and always more or less transparent.

In some places, especially in Muscovy, mica is used for the windows of houses, and is hence called Muscovy glass. It is also used for lanterns, and some purposes aboard of ships, where glass would be liable to break.

STRATA OF ROCKS.

Into the oldest and most common rocks upon the earth, no other minerals enter in considerable quantities

but the three just described. They are the essential, and almost only ingredients in *granite*, *gneiss*, and *mica slate*. In the oldest specimens of granite, usually of a coarse texture, the three ingredients being in large masses, the felspar is most abundant. The mica, frequently in large plates, is dispersed through the mass in every possible direction. As the process of formation continued, the felspar became less abundant, and the mica more regular in its arrangement. The rock hence passed from coarse to fine granite, and from fine granite into gneiss. The last is slaty granite. Both contain the same ingredients, and their principal difference is in the proportion, arrangement, and texture of their ingredients. As the formation of gneiss continued, the felspar still continued to diminish, until it wholly disappeared. When the rock is formed, it is composed of quartz and mica finely mixed, and of a slaty structure, and bears the name of mica slate.

This rock differs from gneiss, not only in being destitute of felspar, but in possessing a finer texture, and a smooth, but frequently an undulating surface.

As these three strata of rocks are more common than any other upon the surface of the earth, they are used for a greater variety of common purposes, by practical men. They are extensively used by farmers for enclosing their fields, and by civil engineers in the construction of roads, bridges, wharves, dams, canals, railways, the walls of buildings, &c, &c.

Nearly allied to granite, and frequently associated with it is *sienite*. In this rock, *hornblende* takes the place of mica in granite; the mass is of course composed of quartz, felspar, and hornblende. The simple mineral last named, sometimes resembles black mica in its external appearance, but is much harder and can be readily distinguished from it, by its resisting the point of a knife, while mica is readily separated into thin scales, by the application of any pointed instrument.

Sienite is found in great abundance in the vicinity of Boston, where it is at present the most common material for the walls of houses and other purposes in architecture. In Quincy, and two or three other towns

in the same vicinity, are deposits of this useful and beautiful rock, in sufficient quantities for building a thousand cities of the size of Boston.

In these deposits, the sienite uniformly consists of three ingredients, though in others, it is formed of two, the quartz being wanting. The three ingredients in this useful material, will be readily seen by a glance at the front of the Tremont House, where three colors are distinctly visible at the distance of several rods. The red and most abundant ingredient is felspar; the white, quartz; and the black and least abundant is hornblende. They are equally distinct in numerous other buildings in almost every part of the city of Boston.

Greenstone, or trap rock, is composed of hornblende and felspar. The former always predominates, and commonly constitutes almost the whole mass.

This rock contains a large portion of iron, and is hence heavy, hard, and more difficult to break than any other stratum. It is, however, intersected by numerous seams, by which it is separated into convenient masses for erecting the walls of houses, for which it is extensively used in New Haven, Edinburgh, and many other places, where it is found in abundance.

Two extensive ranges of mountains in New England, commence with the East and West Rocks, about two miles from the city of New Haven, both of which are greenstone. One continues in the eastern range as far as Greenfield, a part of which are Mount Holyoke and Mount Tom. The other range passes farther west, and extends to the Green Mountains in Vermont.

The Giant's Causeway is a hornblende rock, called basalt.

Sandstone is associated with greenstone, and is always placed beneath it, when they occur together.

This rock, as its name denotes, is composed of sand, or grains of quartz and felspar, with fine scales of mica sometimes dispersed through the mass, and cemented with clay and the oxide of iron.

Many thousand tons of this rock have been carried to Boston from Chatham, opposite to Middletown, on the Connecticut river, and more or less is transported

from the same place into every seaport from New Orleans to Eastport. It is used for the underpinning of houses, door steps, hearths, jambs, &c, &c.

Graywacke, in some of its deposits, resembles sandstone. But besides embracing rocks composed of grains, it extends to those consisting of large pebbles, sometimes a foot in diameter, and frequently so loosely cemented, as to fall to pieces from the effects of the weather, and other gradual operations of time.

An extensive and most singular deposit of graywacke is found nearly the whole distance from Boston to Providence. A circumstance respecting this deposit of graywacke coincides with that in another on the heights of Catskill mountains. The circumstance is, that the highest points of elevation in both cases, consist of the coarsest pebbles. In the descent, both rocks become finer and more compact in their texture, until they finally pass into slate.

Another most singular and unaccountable fact, which is particularly striking in the New England deposit is, that ledges are intersected by numerous seams, which cut, not only the largest pebbles, but the finest grains, leaving a surface almost as smooth as if it were polished. This fact may be witnessed in the numerous walls built of this material in Dorchester and Roxbury, which by the aid of these seams present an even surface in front, notwithstanding the general fracture of the rock is uncommonly ragged and uneven.

The fact is stated merely, any may explain it who are able.

Some of the finest slates, and even the material of which hones are composed, are classed by geologists under the stratum of graywacke.

Argillite, or common slate, used in schools and for the roofs of houses, is an abundant rock, but less common than most of those already described. Extensive ranges of it exist in Vermont, which furnished during the last war, large quantities of a good quality for the roofs of houses. But as it is less expensive transporting it across the Atlantic, than down the Connecticut, the

greater part now used both for schools and roofs, is brought from Wales.

This rock is composed principally of clay, and hence soils, where it abounds, are of the same character. If argillite is put in a road where it will be finely pulverized by wheels, it forms a mass differing but little from a bed of clay.

This rock is neither the most ancient, nor the most recent. It was evidently formed after the primitive limestone, but previously to the secondary deposits of the same rock.

Lime has already been mentioned, both as an ancient and a modern rock. A few ancient deposits are found in New England. Numerous and almost boundless deposits of modern or secondary limestone, are found in New York, and States still more west and south. The masses found in New England are generally of a coarse crystalline structure, those at the west and south, more compact, and they frequently contain relics of animals and vegetables; indeed, in some instances, the whole mass of a mountain appears to be little else than an aggregation of animal relics.

Of no rock is there probably a greater variety than of limestone. It is said there are nearly two hundred varieties of marble, all of which are limestone. The deposits which do not bear the name of marble, probably present an equal variety. Chalk is, strictly speaking, limestone, as it is composed of the same ingredients, and in the same proportion with the quarries wrought for marble, and for the more common purposes of lime.

The Housatonic range of limestone is perhaps the most extensive in New England. It commences in Milford, near the mouth of the river, and extends with some intermissions quite to its head, and even beyond to the St Lawrence river, if not into Canada. The Stockbridge and Middlebury marble, are in this range. In Bolton, and Boxborough, the town north, are deposits of moderate extent. In Smithfield, Rhode Island, is a quarry, from which lime of the finest quality is procured in great quantities. In Stoneham, twelve miles north of Boston, is a small deposit. This resembles

the statuary marble. From Thomastown, Maine, both marble and common lime are procured for Boston market in abundance. In the western part of New England, and the eastern part of New York, is an extensive range, less ancient, than those already mentioned, and less recent than that which constitutes the principal rock in the western part of New York, and the country between that and the Mississippi.

Gypsum, (plaster of Paris,) is one of those rocks which are found in great abundance in a few places upon the earth, but are not common. Nova Scotia, the western part of New York, the vicinity of Paris, France, and a few other places, contain inexhaustible deposits of it. None of consequence has yet been discovered in New England.

Several varieties of this rock are found in abundance, some of which are transparent, crystallized, and beautiful. A common and abundant variety of crystallized gypsum is called selenite, which is in transparent plates or laminae, and resembles mica, and with that has been called isinglass. Their resemblance, however, is merely in their external appearance, their elements being entirely different. Mica is also highly elastic, while selenite is not so, and cannot be bent without breaking.

Gypsum has numerous uses, the most important of which is in agriculture. It has the power of entirely changing the character of some soils, and rendering the most barren, gravelly plains highly fertile. It is more favorable to the growth of clover than any other plant, but promotes the growth of potatoes, Indian corn, and on some soils, of winter grain. It is also used for various ornamental purposes as a plaster.

The ingredients of which gypsum is composed, are lime, sulphuric acid, and water.

Soapstone is composed of talc, with a small mixture of quartz. Both talc, and the rock which it composes are soft, and easily wrought into any shape required by their numerous uses. This rock is hewn into blocks by an axe, separated into slabs by a common saw-mill, or a hand-saw, turned into cylinders or other circular forms by a lathe, and smoothed by a plane.

The ease with which soapstone is wrought, the handsome polish it is capable of receiving, and its power of resisting the effects of heat upon most other rocks, render it extensively useful in the arts. Besides its various uses in connexion with heat, it is preferable to any other material yet discovered for cylinders, used in manufactories for dressing yarn to fit it for the loom. The powder of this stone when mixed with oil, has recently been applied to great advantage to the gudgeons of wheels, axletrees of carriages, and to various other purposes of a similar kind.

Vermont and New Hampshire furnish soapstone in great abundance, and of various qualities. A quarry in Francestown, in the southern part of New Hampshire, has furnished more for Boston market and the various manufactories in New England, than any other deposit. Orford, New Hampshire, contains a beautiful variety. Several towns in Vermont, near the Connecticut river, contain it in great abundance, and of a good quality.

When a rock of a homogeneous base has crystals of a certain character dispersed through the mass, it is called *porphyry*. The base is more commonly some variety of hornblende rock, but sometimes clay-slate, compact felspar, or graywacke.

The crystals usually consist of felspar and quartz, the former in prisms, the latter in pyramids, or small nodules.

The color of porphyry depends upon the base, and the quantity of crystals dispersed through it. Sometimes the base is dark green, and even black, and the imbedded crystals small. Other specimens are composed of a lighter base and more numerous and larger crystals.

Some varieties of porphyry receive a beautiful polish, when it furnishes a valuable material for tables, mantelpieces, and many smaller ornaments, such as butter plates, snuff-boxes, &c.

Vast deposits of this rock are found at Nahant, Lynn, Malden, Marblehead, Salem, Canton, and several other places in the vicinity of Boston. In

these localities, there is a great variety, and some specimens receive a beautiful polish, but have not yet been wrought to any extent. Many of the paving stones in the streets of Boston are porphyry, which are quite distinct after a rain. A part of the Andes mountains are said to consist of porphyry, but the rock is not common.

Amygdaloid somewhat resembles porphyry, as it consists of a homogeneous base, and imbedded crystals. But the base is less various, and usually softer, than that of porphyry, and the imbedded minerals of an oval or spheroidal form, somewhat resembling almonds in shape, and hence the name of the rock.

This, like the rock last mentioned, is sometimes used for ornamental purposes, as some varieties are capable of a good polish, when they exhibit a beautiful complexion and surface.

In Brighton and Hingham, in the vicinity of Boston, this rock is found in large quantities, and in small quantities in the vicinity of New Haven, and a few other places. It is, however, less common and less abundant than the rock last mentioned.

The strata of rocks above mentioned and briefly described, are the principal materials which constitute the mountain masses, and loose fragments or bowlders upon our globe, from which soils are supposed to be formed, and of whose character they certainly partake. Another occasion may admit of a fuller and more accurate description.

At present we can only add a few reasons why geology should be universally introduced as a branch of *common education*. The substance has already been published in the *Journal of Education*.

1. It is nearly allied to geography. The connexion and distinct provinces of these two sciences, have already been pointed out in the introductory remarks of this number. From that view it is believed, many will be ready to acknowledge that the claims of this science to becoming a subject of common school instruction, are equally strong with those of geography, and in some points superior.

2. It is an interesting science. It opens to our view a new world, and presents us with numerous objects of beauty and of interest, before unnoticed. The most barren ledges, the commonest rocks and walls by the wayside, destitute of anything to admire or notice, show to groups of young explorers, that these have not merited the long neglect they have suffered; that they contain much that is rich and beautiful, not merely when arranged on the shelves and cases of a cabinet, but when placed on the mantelpiece of the parlor or drawing-room, and furnishing instruction and delight to the most elevated minds.

3. It is among the grandest of sciences. It leads us to view, with increased admiration, the towering mountain and awful precipice, and induces and enables us to examine with greater ardor and more exalted delight, those features of the earth, which never fail to excite ideas of sublimity even in the rudest mind. We learn from it, that amid the lofty aspect, the terrific grandeur, and the wild confusion of the Alps and Andes, there is order and regularity, which evince the skill of a wise and all-powerful architect. Arrangement amidst apparent disorder, a vast storehouse of riches overhung by forms of terror, objects of the highest beauty grouped beneath the awfully sublime, afford to the passing geologist a moral as well as an intellectual banquet.

4. It gives new interest and increased utility to our journeys and our walks. A person, with the slightest knowledge of geology, never passes from one country or place to another, without finding much to admire, and much to increase his store of knowledge. If he find no thriving village, no field covered with the fruits of the farmer's industry, no fertile tract groaning under its load of stately forest trees, or smiling beneath its dress of beautiful verdure, he still finds in the barren plain or the broken ledge, much that is beautiful, rich, and instructive.

5. It furnishes a healthful and instructive amusement to the young. Wherever it has been introduced into schools, the pupils have taken more or less of their pastime in examining and collecting specimens of min-

erals within their reach. A geological excursion is uniformly preferred by them to their ordinary sports, too often calculated to dissipate their minds, and unfit them for patient and successful application, when they return to their school rooms or their books.

6. It teaches children to be observing. A thousand objects before unnoticed, press upon their view; their imagination and taste are awakened, and called into vigorous and healthful exercise, in discriminating the aspect of objects. Their minds once put upon the search to discover what is beautiful and rich in the mineral kingdom, are led to examine other parts of this wide creation; and wherever they go, or whatever they see, they find something to admire, and to convey to their minds entertainment and instruction.

7. It leads to useful discoveries. Wherever the science of geology has been introduced into schools, or to the attention of other young people, valuable discoveries have been made to enrich the treasures of science, or to furnish new sources of industry and of wealth, both to individuals and the nation. If once introduced into all our schools, the whole country would be put under the most minute and rigid examination, and compelled to yield up its treasures, now buried beneath the surface of the earth. In New England, alone, from one to two hundred thousand young, but ardent and efficient surveyors might be induced to afford their gratuitous and cheerful services, to explore our resources in the mineral kingdom; and while they amused and instructed themselves, they would make important accessions to the public treasures of science and of wealth.

8. As the adoption of geology as a branch of common education, uniformly leads to a thorough examination of the natural features of the country, it would prepare the way for obtaining maps of all the towns where it should be introduced. Considering the trifling expense at which lithographic prints of town maps can be procured, and the important vehicles they would be to convey a minute and accurate knowledge of the character and resources of our country to the minds of its

inhabitants, few subjects better deserve the immediate attention of every town.

9. No science is more practical. It acquaints farmers with the nature of their soils, and the best methods of improving them: civil engineers with the materials for constructing roads, canals, railways, wharves, dams, &c, and the proper method of combining them: artists with the origin and nature of paints, and other substances in common use; and the miner when and how to extend his researches, pointing him to a reward for his labors, and guarding him against abortive attempts.

Agriculture, internal improvements, manufactures, and the various useful arts, occupy, at present, so large a place in public attention, as to render every method which can be adopted to advance them worthy of public and private patronage.

10. The introduction of geology into schools, would tend to promote moral improvement among the young. Perhaps there are not two more unfortunate circumstances attending our system of popular education, than that the exercises of children in the school room are irksome, and those for recreation are dissipating to the mind. If schoolhouses could be rendered places of pleasant resort, and amusements sources of useful instruction, the great work of reform in cultivating intellectual and moral taste would be fairly begun. The more innocent and useful amusements are scattered around the young, the less time and disposition they will have to pursue those which are pernicious or useless. No subject, perhaps, is better fitted to answer the double purpose of amusement and instruction, than geology. And few are better fitted to show the power and wisdom of Him, 'who weighed the mountains in scales, and the hills in a balance.'

11. It is easily acquired. The features of this science are not only striking and grand, but they are few and simple, and exactly fitted to entertain and expand the juvenile mind. By the aid of specimens, with appropriate descriptions, its general principles are more easily and readily understood, than those of any other science which is taught. Nothing is more easy than to

introduce it into every district and private school in the country, and to acquaint every child with the names, ingredients and uses of the rocks he daily observes in his walks, and with the prominent geological features of our country.

12. It is necessary. Without it, gazetteers and journals of travels cannot be understood. In some places, a knowledge of the great geological features of the earth is as common and familiar, as of the continents and oceans; and consequently without this knowledge, a person is liable to find himself ignorant of the most common and familiar topics of conversation, in the society he will frequently meet. To be destitute of a branch of science so important and accessible, is to be unprovided with a great source of mental occupation and entertainment for early life, and in the case of teachers, the want of it is the want of a powerful and happy means of influencing the youthful mind.

If it should be asked how this science can be most readily introduced into schools, it is answered from numerous experiments, that fifty or a hundred labelled specimens, with some small manual to describe them, explaining their ingredients, uses, &c, are sufficient to make a beginning, which if once made, seldom if ever fails to be extended to a general knowledge of the subject.

QUESTIONS.

What two sciences give a description of the earth?

Which gives the names, situation, and number of continents, islands, mountains, &c, Geography or Geology?

Which gives a description of cities, kingdoms, and empires?

Which acquaints us with the ingredients and structure of mountains, islands, and continents, Geography or Geology?

Which informs us of the original structure of the earth, and the various changes it has undergone by earthquakes, volcanoes, and the gradual hand of time?

Are our means of information respecting the original state and numerous changes of the earth, abundant or scanty?

Is the history of our earth which is contained in the first chapter of Genesis, corroborated or annulled by its present state, as learned by Geologists?

What was the state of the earth when 'it was without form and void,' a liquid or solid?

What was probably the solvent power, heat or water, or both?

Have the changes the earth has undergone in coming to its present state, been confined to a few periods, or have they been constant?

In the order of creation, which was formed first, the mineral or vegetable kingdom? the vegetable or animal?

What solid substance was first formed from the general chaotic ocean?

Of how many ingredients is granite composed, and what their names?

Which is coarsest, the most ancient, or most recent granite?

In what kind of granite is felspar the most abundant, old or recent?

For what useful purpose in the arts, is quartz used?

Of what is porcelain made?

Which ingredient in granite has been used as a substitute for glass?

What is the origin of porcelain clay, or kaolin?

Which is coarsest, gneiss or granite?

Which is most of the character of slate?

How many ingredients in mica slate? and are they fine or coarse?

Is mica slate usually even or undulating in its surface?

When granite or gneiss passes into sienite, what substance takes the place of mica?

Is hornblende harder or less hard than mica? which most easily divided into scales?

Is hornblende of a dark or light color?

In sienite, is it more or less abundant than felspar?

In what part of the country does sienite abound? For what purpose is it used?

Which is most common, granite or sienite?

What other rocks except granite, are more common than sienite?

What are the ingredients in greenstone? and which predominates?

Where are extensive deposits of greenstone? Is it a heavy or light rock? hard or soft? easy or difficult to break?

What rock composes Mount Holyoke and Mount Tom?

What rock abounds at New Haven, Connecticut, and in Edinburgh, Scotland?

When sandstone is found in connexion with greenstone, is it placed above or below it?

Of what is sandstone composed?

What place has furnished sandstone, sometimes called freestone, as a building material for most of the cities and large towns in the Union?

What rock besides sandstone, is composed of grains and pebbles cemented?

In deposits of graywacke, which is coarsest, the highest or lowest part of the mass?

What rock abounds between Boston and Providence?

What is the common name for argillite, and to what uses is it applied?

From what place is it obtained?

Has it been wrought from quarries in this country? and where?

Is limestone an ancient or modern rock, or both?

Which is coarsest, the most ancient or most recent?

Are the varieties of limestone few or numerous?

To what stratum of rocks do marbles belong, lime or porphyry?

To what does chalk belong?

Where is gypsum found?

What is the name of that variety of gypsum which resembles mica?

Which is most elastic, mica or selenite?

What is the most important use of gypsum?

What plant is most benefited by it as a manure?

For what purposes in the arts except agriculture, is gypsum used?

What is the principal ingredient in soapstone?

Is it easy or difficult to work?

Does it endure or yield to heat?

Which of the New England States furnishes it in abundance?

When greenstone contains imbedded crystals of felspar and quartz, what is the rock called?

Are the crystals dispersed through porphyry, felspar, or quartz, or both?

For what purposes is porphyry used?

Where is it found?

What rock resembles porphyry?

What is the shape of the imbedded minerals in amygdaloid?

Where is amygdaloid found?

How many letters in the geological alphabet, and what their names?

How many and what the names of these letters in the geological alphabet, which form the greatest part of the rocky and mountain masses upon the earth?

Of what rocks are the highest mountains upon the earth composed?

Of what ingredients are soils composed?

In regions where the rocks are argillite, does clay or sand predominate in the soil?

What are some of the reasons, why Geology should become a branch of common school education?

SCIENTIFIC TRACTS.

NUMBER III.

THE ATMOSPHERE.

PART II.

THE first thing which arrests our attention in looking into the atmosphere, is the blue color of the sky. Philosophy has called upon the science of Optics for an explanation of this effect, and learns that it is caused by the resistance presented by the air to the different rays of light. It is easily shown that the light which comes from the sun, is composed of seven distinct colors, whose blended effect is the whiteness with which we are familiar. These colors consist of red, orange, yellow, green, blue, indigo and violet. The blue ray is supposed to be one of the most difficult of transmission, and is the most readily absorbed by the atmosphere. The red rays, on the contrary, readily pass through the air, while the blue are almost lost. To this absorption of the latter, we are indebted for the bright azure which tinges distant mountains.

As we ascend into the atmosphere, the deepness of its color diminishes, and to the traveller on the Alps or the Andes, the sky appears quite black.

It is to the ready passage of the red ray, that the diver is indebted for his vision in deep water. The red rays penetrate the sea, while the blue are reflected from its surface. From the reflective power of the atmosphere, we derive the delightful twilight before the sun rises, and after he has passed from our view.

The word Pneumatics is derived from the Greek word *pneuma*, which signifies spirit, that being one of the names by which the air was called by the ancients. This term is applied to that branch of natural philosophy which treats of the mechanical properties of the

atmosphere, in contradistinction to the chemical qualities of which our first number treated.

The first inquiry into the mechanical properties of the air, was made in Italy about the year 1640. And we may conclude, that the brilliant display this science now makes, had its origin in the experiments of Torricelli, which were caused by the failure of the mechanics of the Duke of Florence, to raise water in a pump above thirty feet.

That we may fully understand this substance as a mechanical agent, we must examine it a little in detail, and observe its relations to common matter.

It has been already stated that the atmosphere* consists of two distinct gases or airs, in the proportion of 79 parts of nitrogen to 21 of oxygen, and a small quantity of carbonic acid.

All substances in nature considered mechanically, are divided into solids and fluids. By a solid, we are to understand that body or substance whose particles are so related to one another, as not to admit of motion among each other, when any force disturbs the inertia or rest of the whole.

As a fluid we recognise that substance whose particles have a less cohesive attraction, and are easily set in motion among each other by a slight disturbing cause. Besides, when at rest, its surface is uniformly level. This forms a peculiar character of a fluid; while a solid is disposed to continue in that position which followed the impulse.

The philosophical difference of these two conditions of matter, depends on the quantity of heat which each possesses. A familiar illustration is exhibited of the various conditions of the same material, in ice, water, and vapor. Ice at 32° Fahrenheit requires many degrees of heat to liquify it, and when melted, the thermometer shows no evidence of the addition. Water requires many degrees to convert it into vapor, yet this vapor in passing off, exhibits no greater heat than the water from which it is escaping.

* The word atmosphere is derived from the Greek, and signifies sphere of vapor.

The air is therefore to be considered as a fluid, composed of certain particles, separated by the heat diffused among them. An interesting illustration of the separation and repulsion of these particles by heat, is shown in the explosion of gunpowder. This article is composed of nitre, charcoal and sulphur, in definite proportions. Each one of these materials has certain constituents, condensed in the form of a solid. When sufficient heat is applied to overcome their cohesive attraction, these constituents are separated by the particles of heat which enter between them, and which, causing them suddenly to diverge, produce their repulsive power.

The atmosphere extends to nearly fifty miles from the surface of the earth, and bears a similar proportion in its height to the diameter of the earth, as a covering of one tenth of an inch in thickness to a sphere of twelve inches.

By the consideration of the great height of the air, and the materials of which it is formed, we are prepared to commence an examination of its weight. Though its particles are invisible, yet they are attracted to the earth by the same principle as larger perceptible bodies. And consequently, they must exert a specific pressure upon everything on which they rest. No one will deny that a rock or a house has a definite weight. Though these are visible, yet the effect is the same from the pressure of more subtle materials. No one would doubt that the ocean presses with a definite force upon its base. Yet to the eye of the fish, the water is as invisible as the air is to us, and he depends upon his other senses, like ourselves, for evidences of its existence.

Although the atmosphere extends to nearly fifty miles from the earth, we must not suppose that its density is uniform throughout, any more than we would think a pile of cotton of the same height, as dense in the centre as at the base. The density diminishes as we ascend, in certain proportions. For on Mont Blanc, which is about three miles and a half above the level of the sea, the pressure is diminished to one half; proving that one half

of the whole weight exists within four miles of the surface of the earth.

Experiment has proved this weight to be about fifteen pounds on every square inch. If the human body present a surface of eleven square feet, it must sustain a pressure of upwards of eleven tons. And the pressure upon the whole earth, which exposes about 5,575,680,000,000,000 square feet, is equal to about 1,164,201,840,000,000,000 pounds. This seems almost incredible, but we hope to render the fact less startling as we proceed with our illustrations. It may be asked why we are not more sensible of this vast weight. We are so constituted as to require this provision of nature, and from the effect of habit we are insensible to its power. Those who ascend Mont Blanc very sensibly experience a change. They complain of great fulness and distention of the vessels, which arises from the inequality of the external and internal pressures. On the surface of the earth, the forces of the internal fluids are counterbalanced by the atmosphere. And it is owing to the equality of these forces that we are insensible to the existence of either. This is further exemplified in the fish, who is sometimes caught at a depth of 2560 feet, where he is compressed by a force equivalent to eighty atmospheres; yet he is not injured, nor are his motions impeded. The internal pressure of his body resists that from without, and therefore he is perfectly protected. Besides, the pressure he supports, acting in all directions, neutralizes itself by promoting as much as it retards his motions.

Another evidence of the pressure of fluids, is exhibited in the following instance. If we place a weight of any kind upon a thin plate of glass, resting by its extreme edge, it will be instantly broken through, because all the weight is from above. But if the glass be laid on a flat surface, and the weight then gently placed on it, it will not be broken, because the resistance from below is equal to the force from above. If the glass plate were made the bottom of a vessel, and water were poured upon it, it would be destroyed as in the first case. But if it were placed in a vessel at any

depth, so that the fluid were on both sides of it, the pouring in of the water would not injure the glass. If it were even placed several feet below the surface, and were so thin that a few grains would break it in the atmosphere, it would be safe in the fluid, although it might endure the pressure of several hundred weight. These peculiarities depend on the uniform pressure of fluids, which is equal upwards, downwards and in all directions.

RESISTANCE OF THE AIR.

The efforts to prove the mechanical properties of the air, were looked upon with contempt by many who professed a great regard for science. How could it possess mechanical peculiarities, when it appeared to offer no resistance to their motions, permitted the bird to soar to the loftiest heights, and the rain to fall in gentle drops on the tender plant? But the science now exhibits the fallacy of such reasoning, and explains the means by which all these purposes are effected. It tells us man cannot live above a certain distance from the sea; the bird cannot soar beyond a certain height; and that the gentleness of the rain is caused by the resistance the air offers to its fall. Were it not for this cause birds could not rise in the atmosphere. Their flight depends on the resistance the air opposes to their wings. Those birds which fly a long while and far, generally have small bodies and large wings. While those of shorter or less frequent flight, commonly have larger bodies and smaller wings in proportion. These have to beat their wings more frequently in flying, to preserve their velocity and height, and are consequently more easily fatigued.

The velocity of falling bodies is much resisted by the air; and the distance to which projectiles are thrown, is materially affected by this principle. One of the most beautiful illustrations of this resistance is shown in the ascent of the sky-rocket.

The common sky-rocket consists of a simple cylinder of paper filled with gunpowder, or some other explosive material, about six inches long, and about one and a

half in diameter. This is connected with one end of a stick about four feet long, for the purpose of preserving its direction. It will now be recollected what takes place, when fire is applied to the material through the fusee at the lower end of the cylinder. Remembering our description of the inflammation of gunpowder, we perceive that the only exit for this newly formed air, is downward, and consequently, as it rushes out, it meets with the atmosphere, by which its escape is resisted. Hence it must ascend if its weight be not greater than the resistance, and continue its flight until its power is consumed.

PRESSURE OF THE AIR.

We are quite insensible to what principles of philosophy we are indebted for our comforts, and how much has been made subservient to our use by the great artificer of nature. The first act performed by a human being, the process by which the vital current from his mother's breast is made to supply his wants, depends on the pressure of the air. How few have any idea of philosophical aid in what appears to be so simple. But the same may be remarked of innumerable circumstances, which appear to be produced with as little design. Since the attention of philosophers has been directed to these mechanical peculiarities, several phenomena have been explained, which had depended for their solution solely on conjecture. The awful thunder found an explanation in the theory that the lightning in leaping from cloud to cloud, or from a cloud to the earth, drove back the air which opposed its progress, while the atmosphere, rushing in from behind to fill the vacancy, produced the sound which always succeeds the flash.

To Sir Everard Home we are obliged for the explanation of the cause by which flies are enabled to walk on the lower side of a horizontal plane, or the perpendicular surface of glass. He ascertained that their feet have flat skins or flaps, like the feet of web-footed animals, and that they have the power of drawing down this web so closely upon the surface whereon they walk, as effectually to exclude the air. The consequence of

which is, their feet are pressed down upon that surface by the external atmosphere. On this principle, other insects possess the power of locomotion on similar situations. The same law applies to the sea-horse, who is thus enabled to climb perpendicular hills of ice ; and to some kinds of lizard, who ascend vertical walls at pleasure. Many sea-shells depend on this law for their tenacity to rocks. The animal has the power of expelling the air between himself and the rock, whereby he is pressed there with a force proportioned to his size. Cupping, whether affected by a syringe, or by the removal of the air by burning anything in the cup, belongs to the same law. And until within a very few years, the steam-engine, the mightiest of all the inventions of man, depended for its power on the pressure of the air.

Another evidence of the effect of this pressure is shown in the process of boiling. We know by the thermometer, that water boils at the surface of the earth at 212° , and that other liquids require a certain quantity of heat to be absorbed, before they exhibit the phenomenon of boiling. But we find that in proportion as we rise from the level of the sea, these substances do not require the absorption of so much heat, to exhibit the same peculiarities. Water, for instance, boils on Mont Blanc at 180° Fahrenheit; and ether, which boils at the level of the sea at 98° , cannot be retained there in any form, if there be the slightest communication with the atmosphere. This is produced by the diminished pressure of the air ; and in fact, the boiling of water at different heights, if properly attended to, would be one means of ascertaining the height of mountains.

A beautiful illustration of the removal of pressure from the surface of water, may be exhibited by boiling it in a common oil flask, and corking it tightly during the ebullition. The glass being removed from the fire, shows the continuance of the commotion, which may be immediately checked by holding it near the fire or dipping it into hot water. This very curious experiment may be easily explained. The addition of heat checks the commotion by expanding the vapor on the

surface, and thereby increasing its pressure. The application of cold condenses the vapor ; and as the air has been previously driven out by boiling, the pressure is so much diminished, as to offer but little resistance to the escape of vapor from the bottom of the fluid in the form of bubbles.

THE BAROMETER.

The first instrument we shall describe illustrative of the pressure of the air, is the Barometer. This name is derived from the Greek, and signifies a measurer of weight. With this instrument, the famous experiment of Torricelli was made, which he communicated to his friend Viviani, who repeated it in 1643.

The barometer consists of a glass tube about thirty-four inches long, sealed at one end, which, being filled with quicksilver, is inverted in a vessel or cup of the same material. The tube being now held perpendicularly, the fluid will subside from the top, and stand at that height by which it is balanced by a column of atmosphere extending from the surface of the earth to its utmost height. The average height of the quicksilver is about thirty inches at the level of the sea. It is maintained at a certain elevation by the pressure of the air on the surrounding fluid, while that portion over which the tube stands has been relieved from the weight. If water were substituted for quicksilver, it would be supported at the height of thirtytwo feet, because the quicksilver is about fourteen times heavier.

The barometer is commonly used as a weather-glass, and as such, it gives evidence of the changes that are about to take place. The plate connected with the upper part of the tube, is divided into inches and tenths. A movable point, called a vernier, subdividing this division into tenths and hundredths, moves through the centre of this plate perpendicularly. By placing the vernier at the exact height of the quicksilver, we have the height in inches, tenths, and hundredths. The words marked on the plate are not so much to be regarded as the motion of the fluid ; for a deviation from the highest point may be followed by rain, although the quicksilver may

not have sunk below the point marked Fair; and the same may be noticed with regard to its rise.

By this instrument we detect an error very common among mankind, respecting the weight of the air. It is generally supposed that air is heaviest when the atmosphere is cloudy and filled with moisture, and that the languor we then experience is produced by the increased weight upon our bodies. But the reverse is the fact. When the atmosphere is heavy, clouds do not linger near the earth, smoke rises almost perpendicularly, and we experience a peculiar elasticity and energy. When it is light, on the contrary, clouds come very near the earth, smoke falls immediately to the ground, and the animal system feels languid and oppressed. The barometer proves that the weight has been diminished; for the quicksilver, not being counterbalanced by so heavy a column of air, necessarily sinks. Therefore, we find that when the atmosphere is heaviest, our sensations are most agreeable, and when it is lightest, the internal pressure, not being fully resisted, produces the feelings of languor and oppression.

There are four forms of the barometer in use, each of which presents certain advantages.

1st. The portable, or parlor barometer.

2d. The wheel barometer.

3d. The marine barometer.

4th. The mountain barometer.

All these are modifications of the same principle. The first is the simplest, and was described in explaining the peculiarities of the instrument. It acquires the name of portable from the screw which is connected with the cup at the bottom, whereby the fluid can be pressed up the whole length of the tube, to prevent accidents in its transportation.

The second differs very much in appearance; the tube being concealed, and a face somewhat resembling that of a clock, exhibiting the changes by the motion of a hand.

The third differs from the first in having the bore of the tube of unequal diameters, to guard against the accidents by motion of the vessel.

The fourth is so accurately divided as to exhibit the minutest difference in elevation ; and is used for measuring the height of mountains.

Among these the marine barometer presents the most interesting beauties. Its use, however, is not so common as its merits deserve. To those who wander over trackless seas, and along unknown coasts, the ability to discover a threatened change would be invaluable.

Several romantic stories are connected with the history of this instrument ; and all who have experienced its benefits, have some incident to relate illustrating its value. Arnott states that he ' was one of a numerous crew, who probably owed their preservation to its almost miraculous warning. It was in a southern latitude. The sun had just set with placid appearance, closing a beautiful afternoon, and the usual mirth of the evening watch was proceeding, when the captain's order came to prepare with all haste for a storm. As yet, the oldest sailors had not perceived even a threatening in the sky, and were surprised at the extent and hurry of the preparations. But the required measures were not completed, when a more awful hurricane burst upon them than the most experienced had ever braved. Nothing could withstand it: the sails, already furled, and closely bound to the yards, were riven away in tatters: even the bare yards and masts were in great part disabled ; and at one time the whole rigging had nearly fallen by the board. Such, for a few hours, was the mingled roar of the hurricane above, of the waves around, and of the incessant peals of thunder, that no human voice could be heard ; and amidst the general consternation, even the trumpet sounded in vain.

' In that awful night, but for the little tube of mercury which had given the warning, by having fallen with great rapidity, neither the strength of the noble ship, nor the skill and energies of the commander, could have saved one man to tell the tale.'

The barometer is also used for determining the height of mountains. It was the experiment of Pascal with this instrument, that satisfactorily proved the difference

in the weight of the air at various heights, and which established its pressure.

If the atmosphere support a column of quicksilver at thirty inches at the level of the sea, we must infer that the height of the fluid will diminish as we ascend. We accordingly find, by a rough calculation, that an ascent of a thousand feet causes the quicksilver to sink one inch. On Mont Blanc it falls to about fifteen inches, showing an elevation of fifteen thousand feet. And in De Luc's famous balloon ascent, it sunk to twelve inches, proving an altitude of twentyone thousand feet, the greatest height to which man has ever risen.

THE SYPHON.

The name of this instrument is also derived from the Greek, and signifies simply a tube. The syphon is a crooked tube, one leg or branch of which is longer than the other. It is used for raising fluids, emptying vessels, and various hydrostatical experiments.

The principle of the formation of the syphon, forbids a greater height than thirtytwo feet, when the two extremities rest on a horizontal plane. If now the lesser limb be immersed in water, and the air be removed from the tube, the pressure of the air on the surrounding water will force it to pass off through this instrument.

From small syphons, the air may be removed in three ways. 1st. By drawing it out by the mouth; 2d. By a small pump connected with the tube; and 3d. By inverting it, and filling both limbs with the fluid. Then, on immersing the extremity of the short limb, as just described, its purpose will be effected. The explanation of the effect may be understood, by recollecting that each extremity is equally pressed by the surrounding atmosphere; 'but the air not being able to sustain all the water in the longer leg, and being more than able to sustain that in the shorter leg; with the excess of force, therefore, it will raise new water into the shorter leg; and this new water cannot make its way but by protruding the first before it; by this means is the water continually driven out at the longer leg, as it is continually raised by the shorter.'

This instrument is very useful for drawing off liquids without disturbing their sediment. And it may be employed for emptying vessels of any size, or even a lake. It would be an invaluable means of removing water from certain lands which could not otherwise be improved. A tube formed of bored logs, may be laid from the place to be drained, even over a hill, if it do not exceed thirtytwo feet in height, and down its side so far as to make that the longer limb. Both ends must then be plugged, that the syphon may be filled with water, when the plugs may be removed, and the pressure of the air will force out all the water reached by the end of the log.

The syphon will continue to act until all the fluid has been consumed, or that discharged shall have attained a height equal to that from which it came.

There is a pretty toy made on this principle, called the cup of Tantalus, from the mythological fable of the being who was condemned to stand in water up to his neck, and yet to die of thirst. The glass exhibits the figure of a human being standing in the centre. When water is poured into it, it rises until it reaches the neck of the image, and immediately begins to pass off through a concealed syphon, and continues till the whole is discharged.

This instrument also explains the cause of intermitting springs, or those which run for a time and suddenly stop, and then resume their discharge after a certain period. They are produced by the channels through which the water flows, being formed like syphons.

In some places there are springs which run freely in summer or in dry weather, but discharge no water in the winter, or in wet weather. This is caused by a hollow in the hill being fed by runners, but having, beside the vent through which the spring flows, a waste-pipe like a syphon, which carries off the fluid another way, as soon as it is sufficiently high.

Superstitious circumstances are often associated with such springs, but by understanding the principle of the syphon, their marvellous character is easily explained.

ELASTICITY OF THE AIR.

We say that body or material is elastic, whose particles admit of condensation or compression, and an immediate return to their primitive condition, when the compressing power is removed. All aeriform bodies are perfectly elastic, and admit of compression and condensation in the fullest degree. There is no quality of the air so important to the arts as its elasticity. To it belongs the principle of the airpump, the fire-engine, the airgun, the match syringe and the diving bell.

There is no spring worthy of comparison with the elastic power of the air. Load it as heavily as we may, it will sink beneath the weight, but it cannot be broken. Confine it for centuries to the same labor, it is there still, faithful and unworn, ever ready to perform its task. And though the being who confines it for his operations, realizes the value of its power, and sinks down to the grave, it still remains the willing slave of his descendants, until the barriers that confine it, consumed by the accumulated rust of years, refuse to retain the servant longer.

AIRPUMP.

The instrument by which most of the experiments illustrating the pressure of the atmosphere are shown, is called an airpump. Its object is to remove the air from one side or surface of a vessel, that the natural pressure on the opposite side may not be resisted by the pressure from below. We are apt to associate ideas of great complexity with the name of an airpump, when in fact it is among the most simple instruments of philosophy. Any one who has noticed the structure of a common water pump, has seen the whole of the materials used in the other; therefore we will first speak of the water pump, which properly belongs to the pressure of the air, but is introduced here for facility of description, and then show how nearly they resemble each other.

COMMON PUMP.

A pump may be considered as a simple cylinder, with a box or valve fixed at one end, and another, movable by a piston, connected with a handle at the upper end of the cylinder. The first elevation of the handle causes the upper valve to descend, and when it is depressed, the valve is made to rise. The result of this action, when the pump is prepared for use, is to lift the air on the first depression of the handle, and cause a partial vacancy between the lower box and the one that has been raised. The air not being allowed to enter from above through the valve, is removed from the place it had occupied, while that resting on the surface of the water, surrounding the pump, forces it up to supply the deficiency. The piston being again depressed, meets with the water that has passed through the lower valve, which readily lifts the upper box, and passing through it, is easily raised when the handle is again pressed down. A continuance of this action soon produces a regular stream from the spout of the pump.

An effect precisely similar to this, is produced in the elevation and depression of the piston of the airpump. The air passes through its valves in the same manner as the air and water have passed through those of the common pump. The barrel of the airpump is connected by a tube to a flat plate of glass or metal, on which the glass or receiver, as it is called, has been placed to have its air taken away. The principle of the airpump depends on the repulsion or elasticity of the air in expanding by the removal of pressure. At each elevation of the piston a portion of air escapes, whose place is immediately occupied by the expansion of that which remains. This expansion continues until the repulsive powers of the air are no longer able to expel those particles which rest at the bottom of the piston.

The result of the removal of air from a vessel is called a vacuum. This must be produced in all vessels intended to exhibit the pressure of the air. It exists in the barometer between the fluid and the top of the tube, and is called the Torricellian vacuum, which is the most perfect that art can produce.

The first vacuum obtained by mechanical means, was that of Otto de Guericke, a burgomaster of Magdeburg, who, in the year 1654, removed the air from two hemispheres, by the use of a syringe. The experiment he wished to exhibit was the pressure of the air. In this he succeeded, for the continued efforts of twelve horses, pulling in opposite directions, could not overcome the power by which the hemispheres were pressed together.

If we place an inverted tumbler, whose edge has been ground, upon the plate of the pump, and exhaust the air, it will be so firmly fixed as to be difficult of removal. The power required to raise the tumbler, will be equal to the number of square inches it covers, multiplied by fifteen pounds.

The airpump and barometer reciprocally prove each other. The barometer, showing when the air has been removed from a vessel, by the entire fall of the quicksilver; and the airpump proving the fluid is supported by the air, by this operation.

A great number of experiments may be exhibited by the airpump, which the limits of our number will not allow us to describe. Besides it is our object rather to explain principles than to dwell on particulars.

SUCTION.

The cause by which water is generally supposed to be raised in a pump is called suction. But there is not a single instance where it is supposed to prevail, which cannot be explained by the pressure of the air. The term suction is too vague and indefinite for any philosophical purpose, and blinds us to those beauties which nature has presented. The effect from which this appellation will be the most difficult of removal, is that produced by the mouth. Sucking poisoned wounds is coeval with the remotest antiquity, and although the term conveys to our minds a certain operation, yet it does not reveal to us its real features. The application of this word to the process of drinking, would be considered highly vulgar, yet it is performed on precisely the same principle, and in a manner similar to

sucking the poison from a wound. When the lips are applied to a wound, the effort is to remove the pressure of the air from its surface, that the internal pressure may predominate, and force out the exposed fluids, thereby carrying off the poison that may have been mixed with them.

FIRE-ENGINE.

The greatest improvement ever made in this machine, was in the addition of the airchamber. No additional force is gained by its use, nor is its mechanical efficacy increased; for the force requisite to compel the water to enter this chamber, is exactly equal to the elasticity of the compressed air. It is to be considered as a magazine or storehouse of power, which acts uniformly upon the fluid, and forces it out in a continued stream. Besides this, there is an absolute saving of the fluid; for in every depression of the piston of the common force pump, the water being thrown by jerks, a considerable quantity must fall short of the intended object. In the oldfashioned engine, the water could only be thrown by jerks, as the piston was forced down upon the fluid. It is on this principle of compressed air, that the water is raised from the Schuylkill, to supply the city of Philadelphia. It is directed by the power of machinery into the airchamber, whence it is forced upward to a great height on the hill, and empties into the basins, from which it is led to the city.

There are numerous applications of this property of the atmosphere to various artificial fountains. Some of them are so formed as to contain all the air naturally required for their operation. Others depend upon a suitable quantity being first injected by a condensing syringe.

The difference between this syringe and an airpump consists merely in the inversion of both valves, whereby the action of the instrument is reversed. Each valve opening downward, it is easily perceived when the piston is raised, that the air must pass downward through the valve, and when it is depressed, this air not being able to escape upwards, must be forced down through

the lower valve into any vessel connected with the end of the cylinder.

This instrument is called a condenser, and is used in all cases where we wish to force more air into a vessel than it naturally contains. An experiment fully exhibiting this effect, may be shown by connecting with the end of the condenser, a vessel whose only opening has been covered with gum elastic or India rubber. The first depression of the piston will cause this covering to protrude, and a repetition will increase the distention.

AIRGUN.

The most wonderful effect of condensed air is exhibited by the airgun. This instrument differs from a common gun, in having a receptacle for air, which may either be a hollow ball screwed to the lower end of the barrel at its under part, or a cavity in the breech. These chambers, when opened, communicate with the barrel, and when the condensed air is suffered to escape, it rushes into the barrel and drives out the ball with surprising velocity.

It is a curious fact, that, although the airpump is comparatively a modern invention, the airgun, so nearly allied to it in the construction of its valves, should have existed long antecedent to it. For it is recorded that an airgun was made for Henry IV. by Marin, of Lisieux, in Normandy, in 1408; and another was preserved in the armory of Schmettau, bearing date 1474. That in present use is, however, very different in effect from those originally made, which discharged but one bullet after a tedious process of condensation. While the present one may be made to discharge thirty or forty with effect, with the same charge of air.

The airchamber is charged by screwing it to the end of the condenser, and forcing it down suddenly upon the piston, which is securely held by the feet resting on its handle. The air resting on the piston, is thus forced into the chamber through the opening, which is covered by a valve opening inwards. At each depression of the chamber upon the piston, the air is driven upwards, whence it cannot return on account of the valve.

When sufficient air has been condensed, this chamber is to be removed and attached to the gun, which is then ready to receive the ball. This is placed in the mouth of the barrel, and is made to fit closely by first laying it on a small piece of linen, which, when forced down by the rod, perfectly fills the bore.

In discharging the gun, the force of the lock is directed by a small steel piston, moving through a collar, against the valve of the chamber. The air instantly escapes by its side, and rushing into the barrel, drives out the ball. It is necessary to observe, that the action of the lock being instantaneous, the power of the piston is lost after its projection, and it immediately recedes, while the elasticity of the air forces the valve to its place, thereby preventing the escape of more than was intended. The discharges may be continued until the resistance of the condensed air is reduced to its ordinary pressure.

There were two other applications of this principle, recently exhibited in this city, in the model of a cannon and in a common walking-cane, the workmanship of Mr Adam Stewart, an accomplished mechanician. The improvements in his use of the principle, evince great skill and ingenuity in their projector.

The estimates of force possessed by the airgun, when fully charged, have been very various. Even in its earliest days there existed wonderful stories of its power.

By many, the expansive force of the air in the chamber, has been compared with that of gunpowder. But the only opinions worthy of attention are those founded on experiment. The smallest result of the force of gunpowder that we have met with, is that given by Mr Robins. His calculation was, that the elastic force of the fluid produced by ignited gunpowder, is at least one thousand times greater than the ordinary pressure of the air. And if we consider that pressure to be fifteen pounds to the square inch, we have a result of fifteen thousand pounds to every square inch of the surface which confines it.

The ordinary charge of airguns, has been equal to between forty and fifty atmospheres, or between six

hundred and seven hundred and fifty pounds to the square inch. But in the instruments of Mr Stewart, this pressure has been very much exceeded. And we believe he has produced greater condensation in the chamber than any who has preceded him.

The experiments of Bernoulli and Count Rumford, resulted in their belief that the force of ignited powder was at least ten thousand times greater than that of the ordinary pressure of the atmosphere.

According to the smallest calculation, we perceive before these forces can be equal, a pressure of at least fifteen thousand pounds to the square inch must be produced by compressed air.

MATCH SYRINGE.

The match syringe consists of a simple hollow cylinder, closed at one end, and a solid piston movable its whole length. Its object is suddenly to compress the air contained in the cylinder, and render its heat sensible. The assertion that much heat exists in the atmosphere is proved by this condensation. For by compressing the air to a very small space, the particles of heat are brought into so close contact, as to set fire to an inflammable substance fixed in the bottom of the piston. The material generally employed, is a piece of dry lint which has been previously dipped into a solution of saltpetre. The piston, armed with this, being suddenly driven to the base of the barrel, is immediately thrown back by the elasticity of the air, and exhibits the intended effect.

A singular result of this compression is continually shown in the ordinary changes of the atmosphere. Some might suppose that the wind which comes down from a snow-covered mountain, would excite the sensation of great cold. But they must recollect that the density of the air on the earth and on the mountain, is very different. A cubic foot of air on the ground, contains twice as much heat as a cubic foot at three miles and a half from the earth. And consequently, the air which descends is gradually increasing in density, and becomes of a similar temperature by mechanical compression.

Hence, we perceive, it may be the same air which waves the flowers by a warm breeze, drinks the moisture that broods over the lake, and rising with it to the mountain top, deposits it in crystals on its summit.

DIVING BELL.

This is an inverted vessel, perfectly tight at the top and sides, and open at the bottom, intended to carry men down under water, to perform various occupations. Weights are arranged around its lower part to increase its gravity, and cause it to descend perpendicularly.

Its principle may be illustrated by inverting a tumbler in water, and pressing it down to some distance. The inside will remain perfectly dry, proving that the resistance of the air has prevented the water from entering. The water cannot enter without displacing the air, any more than we can place one body in the spot occupied by another, without first removing the original occupant. The only opening in the bell is at the bottom, and the air being lighter than the water, cannot descend to escape; hence it must be condensed by the pressure from below.

A beautiful experiment, illustrative of the value of the diving bell, and of a continual supply of fresh air, may be shown by inverting a large tumbler over a floating lighted taper, and pressing it down to the bottom of the vessel. The taper will continue to float, although sent down the whole depth of the water, and may again be brought to the surface, still burning, if the experiment be quickly performed. If this be not attended to, the flame will be extinguished by the destruction of the oxygen of the air, the place of which will be supplied by the rising water.

The flame may be considered analagous to an individual, as he requires the same oxygen for his preservation which nourishes the flame. And if he be not supplied with fresh air by artificial means, he must soon fall a victim to his temerity.

The invention of the diving bell is universally assigned to the 16th century. Our first information of its use in Europe is that of Taisnier. He relates, that 'at Toledo,

in Spain, in the year 1538, he saw, in the presence of the Emperor Charles V. and about ten thousand spectators, two Greeks let themselves down under water, in a large inverted kettle, with a burning light, and rise up again without being wet.'

After this time it became more known, and is spoken of in the works of Lord Bacon, who describes its effects, and commends its value in facilitating submarine labor.

Among the greatest results of the use of this machine, may be considered those of William Phipps, a native of this country, who, in the year 1683, under leave of Charles II., formed a project for searching for a rich Spanish ship sunk on the coast of Hispaniola. After many trials, he succeeded in bringing up from the depth of six or seven fathoms, treasures to the value of £200,000 sterling. He afterwards received the honor of knighthood, and died in London in 1693.

Diving bells are made of different forms and materials. When made of wood, they are generally about five feet high, four feet broad at the top, and six feet at the bottom. When made of iron they are sometimes of this form, but more frequently are made to resemble the lower half of a cone. The one used at Howth, near Dublin, is an oblong iron chest, six feet long, four broad, and five high, and weighs about four tons. It has two seats capable of holding four persons.

Their descent in water depends on the law of Hydrostatics, that 'a body immersed in a fluid, displaces exactly its own bulk of it.' And consequently, that it may be sunk, it must be made heavier than a bulk of water equal to itself in size. Therefore, in calculating the weight requisite to sink a bell, we first ascertain the number of cubic feet it contains, and knowing the average weight of a cubic foot of water to be about sixtytwo and a half pounds, we multiply the bulk by the weight of the water, and the quotient will be the power requisite to balance the upward pressure. An excess of weight is then added to facilitate its descent.

We are particularly indebted to Dr Halley for the improvements in this machine, and for the means whereby individuals are enabled to continue a long time under

water. He substituted glasses in the top of the bell for the lamp that had been used, and suggested the use of airbarrels, which were sent down by weights, to supply the change of air requisite for respiration.

Before his time many inconveniences were suffered by submarine laborers. The bell was obliged to be frequently raised to let out the contaminated air, and though there have been many suggestions offered since his improvements, yet the bells now made are generally similar to the one he describes.

The machine is supplied with air in two ways, depending on its depth. In the ordinary labors about docks and shallow streams, a force pump, or condensing syringe is connected with a tube which leads to the top of the bell. By this, air may be driven down into it, and the water kept entirely from rising one inch. But when the depth is great, the power requisite to work the pump is greatly increased. For at the depth of thirtyfour feet the pressure from below is equal to fifteen pounds to the inch, and so on in proportion as it descends.

This was remedied by the suggestion of Dr Halley, who sent down barrels of air to an individual, whose duty it was to direct this air into the bell.

The means of communication from those below is effected through cords. Two lines pass from the inside of the machine under the bottom, upward to the hand of a person whose duty is to observe the signals. In the bell, as well as above, is a signal board, whereon those signals are marked. To make this more easily understood, we will subjoin a copy of one of these signal boards, which was used in this city, a few years ago, in building the Marine Railway.

LEFT LINE.	BOTH LINES.	RIGHT LINE.
1 Pull, To the right.	1 Pull, In trouble.	1 Pull, Stop lowering.
2 Pulls, To the left.	2 Pulls, Hoist the bell.	2 Pulls, Lower away.
3 Pulls, Forward.	3 Pulls, Cant the bell.	3 Pulls, Hoist a little.
4 Pulls, Outward.		4 Pulls, Stop hoisting.

When the bell is made of cast iron, the signals may be given in this way or by sounds. A stroke on the bell with a hammer is easily heard above, and a list of

signals so arranged, is used in the manner thus described.

The diving bell has been applied to many useful purposes, as the construction of marine works, the elevation of sunken vessels, and the recovery of treasures from the bottom of rivers.

But one of its most singular applications, has been in blasting rocks at a considerable distance under water. At Howth, in Ireland, persons descended, and drilled and charged the rock, and carried up a tin tube to the surface, through which the fire was to be applied. This was done by dropping a piece of red hot iron down upon the powder.

CONCLUSION.

There is no subject of natural philosophy more interesting than the one we have just considered. It presents so many beauties, and so great a variety, that we are surprised that a substance with which we are so familiar can possess such features.

Until Philosophy began her researches mankind knew nothing of the subtile fluid which surrounds the earth, and which extends so far from its surface. They had no idea of the effect of respiration ; why a flame was enkindled by forcing a current of air through a dull fire, and why fermentation was facilitated by an exposition to the atmosphere. They enjoyed the delightful breeze which gathered the night-dew from the flower, and passed along laden with its fragrance ; but the power of the air was only known to them in the wind, which in its fury lashed the ocean into foaming billows, and swept down the trees of the forest and the habitations of men. They knew nothing of the air but by its effects, as the child observes the motion of the hand of the clock, without comprehending its cause.

There is something peculiarly interesting in the discovery of causes. Effects with which we are familiar soon cease to excite attention, even when the subject is stupendous ; but when we have traced anything, however simple, to its first cause, we experience delight

and satisfaction. How interesting, for instance, is the knowledge of the composition of light, for by an examination of its constituents, we are enabled to account for the color of the sky. How curious is the fact that chemistry exhibits in the composition of the atmosphere, whereby certain proportions of oxygen and nitrogen result in a compound of qualities so useful. In other proportions they form the nitrous oxide or exhilarating gas, and again, in others, nitric acid, or aqua fortis.

The science of chemistry is filled with this variety of combinations of the same materials resulting in different compounds, and by the aid of analysis, the chemist is able to separate the constituents, and explain the cause of the result. He shows us that the difference between the air we breathe, exhilarating gas, and aqua fortis, merely depends on the quantity of oxygen employed; and that the only philosophical difference of ice, water, and vapor, consists in their relative proportions of heat. By experiment, also, Philosophy has ascertained the weight of the atmosphere, and informs us of its precise pressure on the whole surface of the earth. It tells us that the motion of a fly on the perpendicular plane of glass, the process of drinking, and the power of the old steam engine, are effected by the pressure of the air.

By the aid of a very few instruments, all these facts have been discovered, which prove to us that nature develops more curious circumstances than fancy can conceive, and at the same time assures us that her most sublime operations may be explained on the simple principles of philosophy.

SCIENTIFIC TRACTS.

NUMBER IV.

GRAVITATION.

INTRODUCTORY REMARKS.

PERHAPS the reader, on seeing the title of this tract, will be disposed to doubt whether the subject is a useful or interesting one. We all know, it may be said, that bodies fall towards the earth, and what can philosophers teach us in addition to this simple knowledge of the fact, than merely to give to the general law, the learned name of *Gravitation*? Giving a name is no *explanation*.

Let us attend one moment to what is meant by an *explanation*. A savage sees a sailor, who has landed on his shores, point his gun towards the wild animal, bounding through the forest. A flash and an explosion succeed, and the animal stops suddenly in his progress, — falls bleeding to the ground, — and dies. If the astonished native ask *an explanation*, he is told that the instrument which produced the effect is hollow; — that it contained an explosive powder and a heavy ball; — that the gunner's finger, by a motion too small for him to perceive, produced a collision of flint and steel, — and that, by the resulting spark, the charge is inflamed, and the ball is forced through the air, with a rapidity which his eye cannot follow, and which is fatal to the object of its aim.

This is *one* kind of explanation. It consists, as every one will easily see, of bringing to view *circumstances which intervene between the cause and the effect*; and which, before, were hidden. The pointing of the gun is the *cause*, the death of the animal the *effect*, and the collision of the flint and steel, — the explosion of the pow-

der, — and the flight of the ball, are the circumstances intervening, which were unknown to the inquirer until the explanation brought them to light.

Now take another case. A child sees a bar of steel, balanced upon a pivot, in a peculiar case with a glass top. He finds upon moving the case that the bar turns upon its pivot, so as to point in all cases in one direction. He too asks an *explanation*, and is told, that a certain kind of steel bars, when freely suspended, always arrange themselves in a North and South direction.

This is *another* kind of explanation. It will be perceived that it is totally different from the other. It mentions *no intervening circumstances* between the cause and the effect. It merely points out *other phenomena of the same kind*; — shows what is essential in the arrangement which produces this effect, and which will insure its repetition, — and thus, in fine, *describes in general terms the class of phenomena to which this belongs*.

Now it will be evident, by a moment's reflection, that such an explanation as this is nearly if not quite as valuable as the other. Without it the inquirer might be led into a great many errors. He might suppose that the glass, — the shape of the room, — the form of the bar, — the skill of the operator, — were concerned in the result. The explanation has dispelled all these, — pointed out to him what is really essential, — and given him all the knowledge which can be of any practical benefit. There are many phenomena which admit of no other kind of explanation than this; for this simple reason — that in regard to them, we know of no links connecting the cause and effect, — and we must therefore only ascertain what are the circumstances essential for the production of the effect, and give to all the phenomena of the same class one general name. This is what we design to do with the subject before us.

Sir Isaac Newton was the individual whose discoveries brought to view and established the law of gravitation. When first led to think of the subject by seeing an apple fall to the ground, he did not attempt to find an explanation of the kind like the *first* mentioned above; i. e. to discover *something intervening* between the earth and

the apple, which should bring the latter down. His object was to learn what *other* facts were analogous to *this*, and what *other* phenomena were produced in the same way, expecting, when all these should be ascertained, that he would be able to express the whole in general terms, and deduce from them a *general law*. His inquiries were completely successful. He obtained the following general law :

All material objects, have, under all circumstances, a tendency to approach each other.

That this is a universal law, or in other words, that it is universally true, has been proved by observation in a great variety of particulars. These we shall proceed to describe.

1. GRAVITATION BETWEEN THE HEAVENLY BODIES.

For a long time the motions of the heavenly bodies defied all attempts at accurate calculation. The various theories advanced would not account for the facts. The variations from circular orbits, the occasional slight irregularities in some cases returning at regular intervals, and sometimes entirely unexpected, received no solution. But the supposition *that every material body has a tendency to move towards every other*, perfectly explains the whole. Not only are the great regular motions of the various primary and secondary planets about their centres fully explained, but all the exact forms of the curves in which they move, and every irregularity in the motion is fully accounted for by this simple supposition.

The manner in which the revolutions of the planets about their centres is produced, may be thus illustrated.

Suspend by a string from the wall, a small leaden weight. If left to itself, it hangs perpendicularly, and is at rest. If now it is drawn up from the centre, it tends to return to the centre, and will, if liberated, swing to and fro like a pendulum. If, however, instead of simply letting it fall, it is *thrown off upon one side*, it will pass round in an elliptical or circular orbit. It will be very

evident that this motion will be produced by the united influence of the force with which the weight was thrown off by the hand, and the tendency down towards the centre. This last represents gravitation. And although the motion of the weight in this experiment is in many respects different from that of a planet, yet the illustration is good in this respect; viz. it shows how the constant operation of a tendency towards the centre, may cause a body to revolve about that centre in a circular or elliptical orbit.

It will, however, be justly said, that if the tendency of one body to another is universal, it will be apparent not only between a planet and the sun, but between one planet and another. This is the fact. In the adjoining diagram, let S rep-

resent the sun, M Mars, and J Jupiter. Whenever the two planets, in their regular revolutions, pass near each other, each is drawn out of its regular path. Instead of passing in the curves of their orbits, they approach each other and move in the paths rep-

resented by the dotted lines in the figure. When Mars, which revolves more rapidly than Jupiter, passes beyond the influence of the latter, both return to their original paths.

There are many other disturbances in the planetary motions, which no ingenuity could explain before the simple principle of gravitation was discovered. They are so numerous, and correspond so exactly with the theory, as to leave not the slightest room to doubt, that among all the heavenly bodies, sufficiently near us to have their motions observed, there is this uniform tendency to move towards each other.

These disturbances are, however, though great in number, much less in amount than we should suppose by looking at astronomical diagrams. The reason is, that the relative magnitudes and distances of these bodies are very incorrectly represented in these diagrams. If the sun is represented by a ball 75 feet in diameter, the earth would be at the distance of a mile and a half, and would be about the size of a man's head, and the next planet beyond the earth would be three quarters of a mile farther, and about half as large. It is impossible to represent these proportions on paper of a moderate size, and accordingly, in all diagrams the sun and planets are brought much nearer to each other in proportion to their size, than they are in reality. It will be evident, from a slight consideration of the true proportions, that the influence of the planets upon each other must be very inconsiderable compared with that which is exerted upon them by the immense body which occupies the centre of the system.

2. GRAVITATION BETWEEN ONE HEAVENLY BODY AND THE PARTS OF ANOTHER.

If the facts stated under the preceding head were all which had been observed, gravitation would not be proved to be a *universal law of matter*. It would be doubtful whether the attraction which causes two heavenly bodies to approach, was a property belonging to every particle of which each was composed, or whether it pertained exclusively to some substance which each contained, but which formed only a part of each. It might not have been an improbable supposition that some central mass in each might alone possess the attracting power, and cause the bodies to which they respectively belonged, to approach each other. This supposition is, however, prevented by the following facts.

The *Parts* of the earth gravitate towards the heavenly bodies. The waters of the ocean and the atmosphere, the only bodies connected with the earth which are *capable* of separate motion, *have* a motion separate from that of the whole body of the earth. These waters, and this atmosphere rise towards the sun and the moon on

those parts of the earth which are towards those bodies. This conclusively proves that the gravitation of the earth towards the sun and moon is not simply the gravitation of the earth as a whole or of some nucleus in the centre, but of the *various parts* of the earth, as separate and distinct portions of matter.

There is another phenomenon, which was observed long before it was understood, and which is decisive proof of the same point. The earth is not exactly spherical but is fuller in its shape around the equator. Now if the attraction of the earth to the sun is owing to some peculiar substance in its centre, it is plain that this surplus about the equatorial regions will have no effect upon its motions. If, however, this surplus gravitates towards the sun, as all the rest of the matter of which the earth is composed, it is plain that in some peculiar circumstances it may cause a modification of its motions. This last is found to be the fact; and it proves that the solid parts of the earth as well as the liquid and gaseous, have *separately* a tendency towards other material bodies which come into their vicinity.

3. GRAVITATION BETWEEN THE EARTH AND THE LOOSE MASSES UPON ITS SURFACE.

It is scarcely necessary to remark that gravitation is manifested in this case by the falling of bodies, and by their weight. That there is no *one downward direction*, into which all bodies tend, is evident from the fact that upon different sides of the earth, bodies fall in different directions towards it. A stone in America, and another in Asia, falling to the ground, will move directly towards each other. All these motions are evidently the result of a tendency of all bodies to move towards the great mass of matter constituting the earth.

The air gravitates; that is, is attracted by the earth, and *rests with weight* upon it. That portion of the air which is near the surface is loaded with the burden of all that is above, and is compressed by it in a much smaller space than it would naturally occupy. This pressure produces

a great many curious effects.* If a vacancy is anywhere produced, the surrounding air is forced by this pressure violently into it. If the air is removed from a bladder, the sides are forced together, and no effort can separate them so as to leave within an empty space. When the piston or box of a pump rises, it brings up with it the air within the pump; the load of air upon the water around it forces the liquid up into the space thus left. When the air is exhausted by a suitable apparatus from a thin glass vessel, its sides will often be crushed inwards by the pressure of the surrounding air.

It was well known that the atmosphere would rush with violence into any vacant space long before the facts were referred to the right cause, and there was a long and obstinate controversy among the philosophers, whether the phenomena in question were really owing to the weight and pressure of the air, or to what one party called *Nature's abhorrence* of a vacuum. This controversy was at last settled by experiments made upon a certain mountain in the south of France, by which it appeared that the tendency of the air to rush into the vacant space was decidedly less upon the elevation, than at the ordinary level of the ground. Now, as in ascending an eminence, we pass above a considerable portion of the atmosphere, it was natural that what remained above the summit, should press less heavily than the whole. The difference of the effects was therefore very easily accounted for, on the supposition that they were both owing to the pressure of the air; and as it was absurd to suppose that Nature's abhorrence of a vacuum would be less upon a mountain, than in a valley, the advocates of this latter theory gave up the point.†

The gravitation of the air may also be proved, as it often has been, by a very simple experiment. A vessel, filled as usual with air, is weighed. The air is then removed by an air pump, and the vessel, now empty, is weighed again. The difference, which is very sensible, shows the weight of the air which had been removed.

It may be at first imagined that there are some excep-

* See No. II., p. 54.

† See No. III., p. 41.

tions to the remark that all bodies on or near the surface of the earth, tend to move towards it. Smoke ascends; vapors rise; clouds float gently in the sky; and balloons, filled with peculiar gases, soar into the air, bearing with them heavy burdens. These, however, far from being exceptions to the rule, are only instances of its perfect operation. A block of wood, though it has in itself a tendency to fall, will rise to the surface of the water, into which it is plunged. The water having a stronger tendency to move towards the earth, presses down under it, and it rises by the very power of gravitation itself. The gravitating air, in the same manner, forces up the vapor, the smoke and the balloon, all of which would fall with the rapidity of a stone, if nothing resisted their motion.

4. GRAVITATION BETWEEN SMALL BODIES AND PARTS OF THE EARTH.

The facts which have been mentioned under the preceding heads, show the existence and the power of gravitation in cases so numerous and diversified as to render it highly probable that this force is a universal property of matter. There remains, however, much to be added to the evidence; and one very interesting class of experiments are those which show the attracting power of mountains. It was suggested by Newton, that if the law which he discovered were a universal law, a plumb line suspended by the side of a mountain, would deviate from a perpendicular by the attraction of the mountain. The experiment has since been made in two instances, and with complete success. It was first tried in South America, by the side of the celebrated Mountain, Chimborazo, by some French Mathematicians. It was ascertained by very accurate experiments that a plumb line suspended near the mountain was drawn out of its perpendicular towards the mountain eight seconds. This, it will be perceived, is a very small angle, and the deviation would be expected to be small, if we consider how small is the mountain compared with the whole bulk of the earth. There is every reason to place confidence in the correctness of the result.

Not many years after, a similar experiment was tried in Scotland, upon Mt. Schehallien, with a similar result; and the influence of the mountain in drawing the weight from a true perpendicular was established beyond a doubt.*

The particular object of the experiment with Schehallien, was not to prove the *reality* of the attraction exerted by the mountain, for this was considered as previously settled, but, to prove from the amount of the attraction accurately ascertained, the *weight of the earth*. The size of the mountain was ascertained, and also its attracting force, and these were compared with those of the earth, and the result showed that the earth attracted more in proportion to its size than the mountain. The philosophers inferred from this that it was composed of heavier, i. e. denser materials, in the proportion of about two to one.

5. GRAVITATION OF SMALL BODIES ON THE EARTH'S SURFACE TOWARDS EACH OTHER.

The preceding facts and statements, going as far as they do towards establishing the fact that every portion of matter attracts and is attracted by all other matter, will very naturally suggest the inquiry whether this power is perceptible between small bodies on the earth's surface. It will be said that if this tendency of matter to approach matter is universal, two balls placed upon a level table would have a tendency to roll together. This tendency might *exist*, and yet not be easily *manifested*; for an attractive power, which, in so large a mass as the earth, might have power to move rocks and avalanches

* The reader may perhaps have the curiosity to inquire how the deviation of the plumb line from the perpendicular, and particularly its exact amount could be sustained. A telescope was fixed in a perpendicular position by a plumb line, and then moved from its position until it pointed towards a certain fixed star. The distance to which it was moved was noted. The apparatus was then taken to the opposite side of the mountain, and the observation repeated. It was found that the distance to which the telescope was moved, was different at the two stations. This would not have been the fact, if the plumb lines had been parallel. For the fixed star is at so great a distance that its apparent direction would be in both cases the same.

with prodigious violence, might exist in bodies so small, as the balls upon the table, and yet not be sufficient to overcome the difficulties which impede their motion. The little inequalities of the table, too small to be perceived by the senses; the resistance of the air which must be removed from between them if they come together, and the want of perfect regularity in their form, would, perhaps, be sufficient to prevent the motion taking place, when there was a real tendency to it. If the two balls are suspended by strings, and are brought nearly into contact, the obstruction to motion would be less than before; still the balls in moving towards each other must evidently rise slightly, on account of the nature of their suspension. Consequently their tendency to come together must be sufficient partially to *lift* them, or its effects would not be visible.

Various ingenious plans have been devised for suspending bodies in such a manner as to render sensible their gravitation towards each other. An instrument called, from the name of its maker, Cavendish's machine, accomplished the object. Two leaden balls suspended by an apparatus so contrived as to diminish as much as possible resistance and friction, gravitated sensibly towards each other. The method adopted was very similar in principle to that employed by Mr Coulomb, for rendering sensible other weak attractions. This method, very simple and easily imitated, he applied not only to demonstrating gravitation between small bodies, but also to rendering sensible, and to measuring very many other weak forces. His instrument was substantially a bar connecting two heavy leaden balls, *a* and *b*, and suspended by the string *d*, *c*, attached to the centre of the bar. If now a heavy mass be brought near the ball *b*, the latter may move towards it without being lifted at all, for it may move round horizontally only twisting the string *cd*. If it move but little, the twist or *torsion* of the string is a very slight force, and as this is all

which is to be overcome, the whole apparatus is called *the torsion balance*. When a similar contrivance is resorted to to detect and measure weak forces in Electricity or Magnetism, little circles of paper in the former, and small magnetic bars in the latter case, are substituted for the leaden balls. For these purposes, a single silk worm's thread, is generally used for the line to which the bar is suspended.*

By these and similar experiments, the last remaining link is furnished to that beautiful chain of inductive reasoning, by which universal gravitation is established; and the whole series is abundantly sufficient to satisfy any mind by which it is attentively considered, that the great Creator has made it an unvarying and universal law, that every particle of matter draws towards itself every other, and is itself reciprocally and equally drawn. How simple is the principle;—how immense the variety and greatness of its effects! If this single principle, considered in connexion with the unconceivable multiplicity of useful effects which result from it, were the only proofs of *design* which the creation afforded, the Atheist would be compelled as he is now, to abandon reason and argument, and rest his cause on the bad passions and propensities of the human heart.

THE CAUSE OF GRAVITATION.

The question has very often arisen, what is the nature of the connexion between one particle of matter and another by which this tendency to approach is produced? Jupiter and Saturn go out of their respective paths to approach each other. Why do they do it? How is the effect produced? When the stem decays, the apple rapidly goes to the earth.—Is there any intervening substance which communicates an effect from one to the other? Can an explanation of the kind like the first described in the introductory remarks, be given of this

* The writer has a torsion balance, constructed to be used as an electrometer, in which the line suspending the bar of shelleac, is of glass,—a very attenuated thread, spun from window glass by a blow pipe and a lamp.

phenomenon? No explanation ever has been, probably none can be given, — none is needed. The true state of the case is in all probability this: — The Creator has determined that any two portions of matter placed at any distance from each other, shall tend to approach; and by his own direct agency he carries continually this determination into effect. This is all. Not only nothing more has been discovered, but probably there is nothing more to discover. In regard to gravitation, we probably know the whole. It is one of the few cases when the human mind has finished its work. It has reduced the various and complicated phenomena to one single and most simple principle, and the operation it is most philosophical to refer to the Being ‘who upholdeth all things by the word of his power.’*

LAWS OF GRAVITATION.

It remains to point out some simple particulars of the manner in which the principle of gravitation operates, and one who has not much considered the ultimate simplicity which reigns in nature will be surprised at their statement.

The gravitating influence, then, which any portion of matter exerts, may be considered in the following particulars:

1. *It cannot be interrupted or changed.*
2. *It is the same upon every species of matter.*
3. *It is the same at every distance.*

It may seem singular to present seriously and formally such propositions as these, which only state the unchange-

* We use the word *probable*, frequently in these remarks, because it would be rash to say positively that no intervening link *can be discovered* between the cause and the effect in this case. But when we consider that if such a link could be discovered, its own connexions must be sustained by the agency of the Supreme, and when we consider the simplicity and uniformity of the operation of this law, we may, until clear evidence to the contrary is presented, safely consider ourselves as having in this instance arrived at a *Primordial Law of Nature*.

ableness of this principle in its operation. Some very important consequences however result from them, and all the effects produced by gravitation depend upon them. They consequently deserve, each, a separate consideration.

1. It cannot be interrupted or changed.

A stone falls towards the earth as rapidly when some substance is below it, intervening between it and the earth, as without such intervention. In other words, nothing can cut off the communication between one body and another, so as to interrupt the gravitating force which tends to bring them together. If, in the case of the torsion balance, a plate of brass, or of any other substance, is brought between the two bodies with which the experiment is tried, it will not in the least degree interfere with their action. It may perhaps at first view, appear that no one would have expected such an interference. We should naturally have supposed, it may be said, that the interposition of a foreign substance would not cut off the communication. But this impression results from long familiarity with the fact. Young persons are always surprised to see a penknife attracting a magnetic needle through the glass or the wood of the case;—and an excited electric causing the leaves of the electrometer to diverge, when the instrument is enclosed in an air-tight glass case, is often exhibited to a class in Philosophy as a wonderful phenomenon. No reason can be assigned, why the attraction of gravitation should act through an intervening substance, more than that of electricity and magnetism, or why the mind, which is surprised at it in the former case, should consider it a matter of course in the latter.*

As the gravitating power of matter cannot be cut off,

* The attraction of magnetism is cut off by the interposition of an iron plate. A curious subject, of a moment's reverie, may be furnished by reflecting on the complete revolution in the arts and the business of life, which would be produced by the discovery of a substance, which would in the same manner interrupt gravitation, and thus enable man to destroy weight at his pleasure.

so it cannot be changed or taken away. Heat a magnetic needle, and it loses its power. Touch an excited electric, and it will attract no longer. But a bullet or a stone can by no human skill be deprived of its weight. The Creator has made this principle the inseparable and immutable property of every material object which he has formed.

2. *It is the same with every species of matter.*

This may at the first sight appear untrue. For it will at once occur to the reader, that since gravitation is the cause of weight, and some bodies are much more heavy than others of the same magnitude, there must be a difference in the gravitating power. For example, since a ball of lead falls much more rapidly and with much greater force than a ball of cork, it might be inferred that the gravitation of the former is much greater than that of the latter.

But there is another way to account for the rapidity and force with which lead descends; *i.e.* by supposing that there is *more* lead than cork in balls of equal size. The structure of the cork may be such that the particles are not compact together, so that they may be three times as many particles of lead in the same space. If this were true, the whole mass of lead would fall with *three times* the force, if every particle, whether of lead or of cork, were attracted alike. Now as the *force* with which the ball of cork would fall, must be less than that of the lead, its velocity must be less too, for it has the same quantity of air to remove from its path, and less power with which to remove it. It would therefore be more retarded.

If now the atmosphere is removed, and the two bodies are allowed to fall through empty space, they will fall together, if both kinds of matter are attracted equally. For if each is drawn in proportion to the quantity in each, it is plain that they will be equally affected. This experiment has often been tried;—it is called the guinea and feather experiment, because a guinea and a feather have been often used as the light and heavy bodies. A tall glass vessel is fitted to the air pump, with the

guinea and feather so fixed at the top, that they can be dropped by touching a wire. They go exactly together to the bottom;—which shows that the air is the only cause why the feather usually falls more slowly.

It will be very evident that the constitution of nature might easily have been such, that some species of matter would have been more strongly attracted than others. It may be a subject of interesting reflection, to consider, what would have been the effects of such an arrangement, and by what phenomena such a fact would be made manifest.

3. *It is the same at every distance.*

This statement will excite surprise also until it is explained. Let *A* be

any body of matter, and *cde*, and *fgh*, represent concentric spheres around it.

Now, what we mean to say is, that the force of attraction which *A* exerts, at the distance *cde*, in every direction from *A*, that is, in the whole sphere, will be the same which

it will exert in the whole sphere at *fgh*. In other words, the whole amount of force exerted in every direction, by a body, at any distance, is the same with the whole amount in every direction, at any other distance.

It will be evident from this principle, that, since the whole amount is at every distance the same, and as the sphere of influence increases the farther we go from the body,—the force at any one point must be less. In other words, as the power of gravitation extends in every direction, the farther we go from the body, it is, as it were, diffused over a greater space, and consequently will be, in any one point, weakened by this diffusion. For

example, let A be the attracting body, and b another body which it attracts; now from what was stated before, it will

readily appear, that the force of gravitation exerted by a , between the points c and d , is the same with that between b and e . But at d , the body is under the influence of only half this force, for all that part which is between c and e does not act upon the body, whereas at b it feels the whole. It would appear therefore from this diagram, that if we double the distance of any attracted body, we diminish the amount of force which acts upon it by *one half*. This however is not strictly true, for the preceding diagram represents only a part of the increase of

space, in receding from a point. In the adjoining figure, where c represents the centre, and oc , od , &c, lines diverging from it, and b and a corresponding spaces at different distances, it will be seen that b is *more* than twice as large as a , for it doubles in *length*, and also in *breadth*; it is consequently *four* times as large. If b were *three* times as far from o , as a is, it would accordingly be *nine* times as large. Consequently the force of gravitation, in order to be equal at every distance, must be diffused, as it were, in proportion to the square of the distance; and as the power over any particular body will be inversely as the diffusion of the force at the distance of the body, it follows that *this power* will be inversely as the square of the distance. This result, it is necessary for the reader fully to understand, and to fix in his memory. It is considered a fundamental law. Expressed in general terms it is as follows :

*The force of gravitation exerted by one body upon another, is inversely as the square of the distance of the bodies.**

* This is usually stated at once as the fundamental law of gravitation, and not deduced, as we have done, from the simpler state-

This will be easily understood and remembered, if the reader is careful to notice the distinction which is made between the *whole force exerted in every direction*, by any central mass, which *whole amount* is, at every distance, the same, and *that particular part of this force*, which operates upon an attracted body, when placed at different distances; this *particular part* being inversely as the square of the distance.

How simple and beautiful are these laws. They are not exceptions to the general principle, nor even modifications. They are, on the contrary, simple assertions of its unvarying uniformity. From these, however few, and simple, and negative in character as they are, every one of the complicated and powerful effects of this principle can be mathematically deduced. The motions of the heavenly bodies in their orbits, — the exact curves which they describe, — every deviation from their regular paths; — the tides, both aqueous and aerial, with all their fluctuations; — the path of every cannon ball; — the velocity of every falling stone, and the rapidity of the vibrations of every pendulum, — can all be accurately calculated and ascertained, from this simple principle of an attractive power, exerted by every particle, which, under all circumstances, and at every distance, remains invariably the same.

EFFECTS PRODUCED BY GRAVITATION.

It is not possible to consider within the limits of the present number, the various and complicated effects produced by gravitation. Their variety and complication arise from the operation of this principle *in combination with others*. Strictly speaking, *gravitation* never produces but one effect, and that is a tendency of one body to approach another, in the inverse ratio of the square of the distance. This simple effect is, however, modified

ment, that gravitation is the same at every distance. When it is so stated, the young scholar is often surprised that Providence should have adopted that exact mathematical ratio of decrease. This surprise is removed by considering the subject in the light in which we have presented it.

by the presence, and contemporaneous action of various other principles.

There is only one class of these effects, which properly comes within the scope of our present design; and that is the case of bodies *falling freely*. This subject we shall proceed briefly to investigate. The result to which we shall come, and which is called the general law of falling bodies is this —

The spaces passed over by falling bodies are as the squares of the times.

That is, if one body is falling one minute, and another two minutes, the spaces which they will respectively describe, will be as *the squares* of those numbers, so that the second will not fall simply *twice* as far as the first, but *four* times as far. For as the square of 1 is 1, and of 2, 4, the spaces will be as 1 to 4. In the same manner, if one body fall 2 seconds, and another 3, the number of feet of the respective descents will be as 4 to 9, for 4 is the square of 2, and 9 of 3.

We cannot here give the mathematical demonstration of this principle, but to illustrate it a little, let the reader imagine a mass of rock loosed from the edge of an overhanging cliff. No one doubts that the impetuosity of its descent will be increased by the distance it has to fall, but every one has not a distinct idea of the nature and cause of this acceleration. In order to understand this, let us think of its condition after it has fallen through the first ten feet of its descent. Suppose that, at this point, the force of gravitation should suddenly cease, would the rock stop in its descent? By no means; it would go forward *with the velocity which it had previously acquired*, precisely as the cannon ball continues to move swiftly through the air, after the explosive force of gunpowder ceases to operate upon it. The impulse given in this latter case is over in an instant, but the motion continues until the resistance of the air extinguishes it. In the same manner, if the force of gravity were to cease at the end of the first ten feet of the fall of the rock, the mass would move on, with the velocity which it had already acquired, to the earth, excepting that it might lose a little by the resistance of the air. But gravitation does not

cease. It gives new impulses every moment, which come in to increase the last acquired velocity. Now it is *this constant and regular acceleration*, which gives to the motion of falling bodies their chief peculiarity, and from this it results, that at the end of 1, 2, 3 and 4 seconds, the spaces through which the body will fall, will be as 1, 4, 9 and 16, which are the squares of the numbers representing the time.

It has been found by experiment, that a body falling freely, passes through 16 feet and 1 inch in one second; in 2 seconds it will pass through 4 times that distance; in 3 seconds 9 times, and so on. From this, a little arithmetical ingenuity will easily calculate the distance, through which a heavy body will fall, in any number of seconds. The height of a precipice, or the depth of a well may be, by the assistance of a stop watch, measured on this principle, though the result may not be very accurate.

DISCOVERY OF THE PRINCIPLE OF GRAVITATION: SIR ISAAC NEWTON.

The subject of gravitation suggests to the mind of every reader, the name of the great English Philosopher, Sir Isaac Newton. We cannot more appropriately close this treatise, than by describing some of the leading incidents in his life.

He was born about three hundred years ago, in Lincolnshire, England, at a place called Woolsthorpe. He was so small, and feeble in his early infancy, that little hope was entertained of his life. This has been the case with many individuals, who afterwards attained to high intellectual eminence. His father died before his birth, but his mother did all in her power to provide for him the means of education. At one of his schools, he displayed a very singular capacity for mechanical contrivances. 'By means of little saws, hatchets, hammers, and all sorts of tools, he made models of wood, when his companions were at play; and such was his dexterity, that he constructed a wooden clock, and a good model of a windmill, which was erected about that time in his neighborhood. Into this model he sometimes put a mouse,

which he called his miller, and by means of whose action he could turn the mill round when he chose. He executed also a water clock, about four feet high, with a dial plate at the top for indicating the hours. The index was turned by a piece of wood, which either rose or fell by the dropping of water. The passion for these mechanical occupations, often withdrew his attention from his regular studies; and in consequence of this, the other boys gained places above him, till he was roused to outstrip them all by a little extraordinary exertion. The intermission of his mechanical pursuits, which was thus rendered necessary, rather increased than abated his ardor for them. He introduced the use of paper kites among his school-fellows. He made paper lanterns, by the light of which he went to school in the winter mornings; and he frightened the country people by tying them to the tails of his kites, in a dark night. He watched too the motions of the sun with great diligence; and by means of pegs placed in the wall of the house where he lived, and marks for the hours and half hours, the time of the day was shown to every person, on what went by the name of Isaac's dial. He had also a great turn for drawing; and, according to the account of Mrs Vincent, who was niece to the wife of Sir Isaac's landlord, at Grentham, he frequently made little tables and cupboards for her and her play-fellows. She mentions also his having made a cart with four wheels, in which he could drive himself by turning a windlass.'

Young Newton was, before a long time, recalled from school, to assist his mother in managing the farm. But he did not succeed very well in this employment. His taste for mechanical employments continued, and he felt very little interest in the labors of the plough and the hoe. Sometimes he went, with another person who was employed upon the farm, to a neighboring town to market, to sell their produce. In such cases he frequently left his charge, and spent his time at an apothecary's, where he found books which interested him, leaving his business in the hands of his attendant. He was not always faithful to his duties at home. 'The study of a book, the execution of a model, or the superintendence

of a water-wheel of his own construction, often occupied his attention when the sheep were astray, and the corn was treading down by the cattle.' This was wrong. No interest in science, or desire for intellectual improvement, can excuse *neglect of duty*, and especially any unfaithfulness to a trust reposed by a parent.

Not long after this, Newton, at the age of eighteen, entered the University at Cambridge. Here he soon became distinguished for his interest and progress in mathematical science, and soon after receiving his degree, he turned his attention to some experiments upon light and colors, which, however, we must not stop to describe. The plague soon after broke out at Cambridge, and to avoid it, he retired to his former home. Here he spent two years, and during this period of retirement and seclusion, he made the discoveries in regard to gravitation, which have immortalized his name. One day, when he was seated alone in a garden, the fall of an apple arrested his attention. Why should it go towards the earth? was the question. A common mind would have been satisfied with saying, that the support of the stem was removed, and that it fell of course. This, however, did not satisfy our philosopher. He reflected on the subject long. It was not that the fall of the apple appeared *new* to him. It was only the occasion, which led his mind to reflect on this universal tendency towards the earth, with which, as a fact, he had long been familiar. He considered, that this tendency towards the earth, was the same in all parts of the earth, and at all places. It was not sensibly increased or diminished, in deep valleys or on lofty mountains. It occurred to him that the power might perhaps extend far from the earth, into the regions of the air. It might possibly affect the moon, and if so, —if it should prove that the moon was constantly under the influence of an attraction towards the earth, —the nature of her motion in an orbit would be at once explained, and all the cumbrous perplexities of former philosophers, to account for the celestial revolutions would be ended at once. 'I will make the calculation,' thought he, 'and ascertain whether the motions of the moon correspond with such a supposition.'

*Now, although the force of gravity might not be sensibly less, at the tops of the highest mountains, than at the ordinary level of the earth's surface, he conceived it to be very possible, that at so great a distance as that of the moon, it might be considerably different. 'To make an estimate of what might be the degree of diminution, he considered that, if the moon be retained in her orbit by the force of gravity, no doubt the primary planets are carried round the sun by a like power; and by comparing the periods of the several planets with their distances from the sun, he found that if any power like gravity kept them in their orbits, its strength must decrease in proportion as the squares of the distances increase.'

Supposing therefore, that the force of gravity decreased, *i. e.* so far as its operation upon particular bodies is concerned, in the above named ratio, he proceeded with the laborious calculation. The result disappointed him. It did not correspond with the fact. The hopes which he had cherished of throwing new light on this subject were blasted, and he gave up the consideration of it.

The reason of this failure was, however, an error generally prevalent at that time in regard to the size of the earth. He supposed it smaller than it really was. This affected the calculation so as to produce the wrong result which had discouraged him; and it was not until several years afterwards that he discovered this cause of error. When he did discover it, he resumed the calculation. As his work, on this second attempt drew towards the close, he foresaw the successful result. The joy of attaining success after a previous failure,—the magnificence of the expected discovery—the changes, which he could easily foresee would be produced in the opinions of mankind on this subject,—the rapid advances which astronomy might now be expected to make, all burst upon his mind, bringing with them so many agitating emotions, that he could not complete his work. He was obliged to call in the assistance of a friend by whom the result was obtained.

We cannot follow this great philosopher through the remaining incidents of his life. He pursued with much diligence and success his mathematical and philosophical

studies, and became sometimes involved in controversies in defence of his opinions. These he much regretted, for he was of a mild and peaceable disposition. His character was marked with almost all that is excellent. There were no eccentricities cherished,—no singularities in manners or opinions;—he was kind to others, modest and unassuming in regard to himself;—he depended on patient, persevering effort for his success in all his efforts, and by his constant fidelity, in the discharge of the duties of social life and religion, he seemed to aim more at happiness, than at fame.

QUESTIONS.

What is the law of gravitation ?

Is the truth of this to be proved by theoretical reasoning, or by the observation of facts ?

What is the first class of facts named ?

Has it always been known that the revolutions of the planets were caused by the attraction of the central body ?

Is there any other evidence of attraction between celestial bodies, besides the attraction of the *sun* for the *planets* ?

What effect is produced by the attraction of the planets for each other ?

Are these disturbances of the regular motions numerous ? Are they great ?

What is the second case in which the operation of gravitation is pointed out ?

What parts of the earth are capable of a separate motion towards the sun and moon ?

What is the third class of facts named ?

How is the attractive force of a mountain made evident ?

Upon what mountain was the experiment first tried ? Was the effect perceptible ?

Upon what other mountain has the experiment been made ?

Were the effects produced very great ? How much did the plumb line deviate ?

Is there any other way in which gravitation has been made apparent ?

Can you name any of the general laws of gravitation?
What is the general character of these laws?

Can the force of gravitation be in any way intercepted? Can it be weakened?

Is *the whole amount* of attractive force exerted by any body the same on different distances?

Is that part which is exerted at different distances, upon the same body, the same?

Can any reason be given why bodies should attract each other?

Mention some of the leading particulars in Newton's Life?

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'Popular Education and the increased study of Mathematics, as the proper foundation of all useful knowledge, seem to call especially for elementary treatises on Geometry, as has been evinced in the favorable reception of the first edition of this work within a few months of the date of its publication. A few changes have been made in the present edition, which, it is hoped, will contribute to the usefulness of the work as a book of elementary instruction.

'As regards the use of it in schools and seminaries, the teacher will find sufficient directions in the remarks inserted in the body of the work.

At a late meeting of the School Committee of the city of Boston, Mr Grund's Geometry was recommended as a suitable book to be used in the Public Schools. Similar testimonials of the merits and usefulness of the work have been received from Teachers and School Committees, in various parts of New England.

C. H. & B. have in press and will publish in a few weeks, 'A Treatise on Solid Geometry, by Francis J. Grund: intended as a Sequel to the 'First Lessons in Plane Geometry.' Apparatus has been prepared by Mr Josiah Holbrook, calculated to illustrate the Problems contained in the above work.

SCIENTIFIC TRACTS.

NUMBER V.

ANIMAL MECHANISM.

THE EYE.

BY JEROME V. C. SMITH, M. D.

A VARIETY of professional works are already before the public on the anatomy of the eye, but it is questionable whether any of them are sufficiently divested of technical language, to be of utility to that class of readers who are only interested in the beauties of science.

Without making pretensions to originality, the writer of the following pages will endeavor to simplify a subject, too generally considered abstruse, that it may be understood by those who have neither patience, time, nor inclination to pursue it under the guidance of a public instructor.

Well acquainted, as anatomists are, with the minute organization of the eye, no one has been able to explain *how* or *why* we see. Although the visual organs are constructed with such exact reference to the laws of light, that telescopes and microscopes, made upon truly philosophical principles, are but imitations or modifications of the apparatus of the human eye,—there is still a difference between the animate and inanimate, the most wonderful and astonishing. The first is a *perceiving* instrument; the second, a *receiving*.

The eye can only perform its destined functions, in connexion with a living system, regulated by an existing harmony of all its complex machinery, consisting of nerves, blood vessels and brain. However perfect in its several tunics the eye may be, or transparent in its fluids,

if the sensorium become disordered by disease, it no longer recognises the images or impressions transmitted to it through the visual nerve. Thus it will be understood, that the eye may labor, receive, and transmit a miniature picture of all it perceives to the soul; but, if there is a derangement of that mass of mysteriously constructed matter, filling the whole skull, which all experience demonstrates to be the seat of thought, no idea is excited. On the other hand, when individuals suddenly lose their sight, without materially injuring the optic nerve, they sometimes dream of seeing. In this case, imagination excites the nerve in such a peculiar and inexplicable manner, as to call up the idea of vision. This nerve being formed with exclusive reference to that function, in the economy of animal life, any impression upon it will excite a corresponding impression in the brain, and no other.

All creatures, from man downward, living on land, have their eyes very similar in structure. The same quantity of light that enables a man to see distinctly, will also answer for a horse, an ox, and, indeed, most of the domestic and graminivorous animals. A natural inference would be, then, were it not otherwise known by dissection, that all the parts entering into the composition of their eyes, in order to produce the same effect as in man, were of the same materials.

In carnivorous animals, the original principle of vision is preserved, but most curiously modified, according to their habits and characters. Those that feed on herbage, are commonly of social dispositions, feeding in companies through the day, and quietly ruminating or sleeping through the night.

Those, on the contrary, that live by violence, preying on those they have slain, are generally solitary: they lie in ambush, alone, watching for their victim; and it is so ordered, by the immutable laws of nature, that they slay such as are more timid and helpless than themselves. In order to accomplish this, with the greatest certainty, carnivorous animals have the power of seeing in the dark.

Fishes, by a further modification of the original appa-

ratus, common to all others, probably see with peculiar distinctness, in the darkest night, at unfathomable depths of the ocean.

With another alteration, not unlike changing the distances between the lenses of a spy-glass, another family of animals, as seals, &c, see alternately in two elements. Still further, on the descending scale of creation, insects are provided with motionless eyes,—giving them the faculty of seeing in every possible direction. And, lastly, in snails and some kinds of worms, the eyes are fixed at the extremity of a moveable feeler, adapting them to different focal distances,—or they can be drawn entirely within the head, for safe keeping, when not in use, precisely on the same principle of care that we draw out the slides of an opera glass, and close them up again, when no longer needed.

Were we desirous of describing the nice variations in the mechanism of the eyes of the several species of animals adverted to in this preliminary, however interesting it might be to some, would, perhaps, appear tedious to others. Confining ourselves, now, to the exclusive consideration of the human eye, we shall proceed with an orderly description of its several parts,—hoping that the few scientific terms which must necessarily be retained, will not prove to be a serious embarrassment.

THE SOCKET IN WHICH THE EYE ROLLS.

Several thin pieces of bone assist in the formation of the orbit, which, in a dry skull, is shaped much like a pear, with its large end turned outward. The upper plate of bone is arched, slightly resembling an arch of a bridge, having the brain resting on it above, and the eye ball moving under it below. Externally, the eyes are at considerable distance, but the inner termination of the conical orbits, answering to the small end of the fruit, are quite near together. At their points, is a ragged hole, in each, through which the nerve of vision enters the brain. A large quantity of fat is deposited in this socket, between the bones and eye-ball, that the latter may always move with perfect freedom, and without friction, in all directions. After a long sickness, this cushion of fat is

absorbed, with that deposited in the bones, to sustain the system, which accounts for the sinking in of the eye: as the person recovers, the stomach resumes the task of taking care of the body, the fat is deposited again, and the eye becomes prominent as before.

GLOBE OF THE EYE.

When detached from the surrounding parts, the eyeball does not appear exactly round: it is, in outline, more than two thirds of a large sphere, with a portion of a lesser globe laid upon it.

The use of this arrangement is obvious. If the ball had been actually round, the compass of vision would have been very limited: as it is, the smaller portion, by its short curve, protrudes so far beyond the socket, where the globe is lodged for safety, that the sphere of vision is very much enlarged.

MUSCLES OF THE EYE.

To move the ball, cords, called *muscles*, were necessary; otherwise, animals would have been obliged to turn their bodies as often as an object was to be seen. Of these, four are straight, going from the sides of the ball, to be fastened near the hole, at the termination of the bony cavity: their office is to hold the eye firmly, in a fixed position, as in steadily contemplating a painting. Two others are given, making six in the whole, to express, principally, the passions of the mind: they are denominated the *oblique*, in consequence of their oblique movement of the eye. One rolls it downward and outward, as in viewing the shoulder; the other, going through a loop, which is so purely mechanical, that it has been the theme of admiration with philosophers in all ages, carries it upward and inward. The last action can be shown by looking at a button, held on a line with the nose, midway of the forehead. Although these oblique muscles exist in monkeys and nearly all tribes of quadrupeds, they are imperfectly developed; showing most conclusively that they were designed for expressing the feelings and passions of man—an ineffable language,

which all the brute creation have the sagacity to understand. When one of the four straight muscles is shorter than its fellow on the opposite side, it produces the *cross-eye*, or squinting.

FIG. 1.

Explanation of Figure 1.

This plan, from a careful dissection of the right eye, exhibits the muscles, viewed obliquely from its upper and outer side.

a — The eye-ball.

b — Part of the upper eye-lid.

c — *Tunica Conjunctiva*, or inclination of the common skin of the forehead, which turns over the edges of the lids, and is finally carried over the front of the globe, but is perfectly transparent at this point.

d — The integuments of the right side of the nose.

ee — The optic nerve.

f — The four *straight muscles*, with the *levator*, or *raising muscle* of the upper eye-lid, together with the *superior oblique muscle*, embracing the optic nerve where it enters the orbit.

g — The levator of the lid drawn aside.

- h* — *Levator oculi*, or superior straight muscle, — to roll the ball upward.
i — *Abductor oculi*, rolls the ball outward.
k — *Adductor oculi*, rolls it towards the nose.
l — *Depressor oculi*, rolls the ball downward, towards the cheek.
m — The *superior oblique* muscle, passing through a loop at *n*.
n — Called the *trochlea*, or pulley, but, in fact, a simple loop.
o — Insertion of the *superior oblique muscle* in the eye-ball.
p — The *inferior oblique muscle*, taking its rise from a bone.
q — The insertion of the tendon of the *inferior oblique muscle* in the first coat of the ball.

COATS OF THE EYE.

Such is the mechanical arrangement of the different coats or coverings of the eye, answering in use, to the brass tubes of a spy-glass, that one is fitted within the other, like a nest of boxes: they are three in number. Anatomists, however, make minute subdivisions of these, of no practical benefit to themselves or others.

Explanation of Figure 2.

FIG. 2.

This is a plan of the coats, or as they are termed in anatomical works, *tunics*.

Reference should be made to this after reading the text. The natural figure of the eye, in outline, is preserved.

a — The *Sclerotic*, or first hard tunic.

b — The *Choroid*, or fleecy tunic.

c — The *Retina*, or third and inmost tunic, which is an expansion of the optic nerve *g* — the certain seat of vision.

d — The *Cornea*, or prominent, transparent circle, over which the lids close, in winking, — hereafter to be described.

e — The *Crystalline lens*, or little magnifying glass of the eye, about a quarter of an inch in diameter.

f — Is the space filled by one of the fluids of the eye, and called the *anterior chamber*.

g — The stump of the optic nerve, which is prolonged into the substance of the brain.

1st. The first is the *Sclerotic** coat, thick, firm and possessing but little sensibility. Its hardness gives security to the delicate membranes beyond; affords attachment for the muscles; and by its elasticity, equally distends the ball, that none of the humors may suffer from pressure. Happily the hard coat is very rarely diseased. Fishes have a sclerotic coat strictly hard, being either cartilaginous or firm bone, graduated in this respect according to the depth to which they descend in search of food. Without this compensation, the great weight of the water above would crush in their eyes instantaneously. Through this coat, in what is called the white of the eye, the oculist plunges a needle to cure some kinds of blindness.

2d. *Choroid*† is the name of the second coat, having a dark red color, and apparently slightly connected with the first. By carefully cutting off the sclerotic from a bullock's eye, with scissors, the choroid will be beautifully exhibited, sustaining the humors. Minute dissection, under a microscope, shows this tunic is a complete web of arteries and veins;—hence its reddish hue. Between this and the sclerotic, fine silvery threads are seen, which hold a control over the *iris*, yet to be described,—determining by their influence how much or how little light may safely be admitted into the eye. Fungous tumors have their origin in this coat, growing so rapidly as to burst the sclerotica, pushing their way out of their orbit down upon the cheek, incorporating the whole ball in one prodigious mass of disease. The inside of this membrane resembles closely woven wailed cloth, having a fleecy nap, similar to velvet, called *tapetum*.‡ This tapetum is particularly interesting in a philosophical point of view, as on its shade of color, in a great measure, as will be more fully explained in the sequel, depends the power of seeing in the dark.

3d. *Retina*,§ so called from its resemblance to a net, completes the number, being the innermost and last. Its

* *Sclerotic*, from a Greek word meaning hard.

† *Choroides*,—like a lamb-skin, fleecy.

‡ *Tapetum*—resembling cloth, called tapestry.

§ *Retina*—a net.

color is that of gum arabic, or ground glass: nothing can be more delicate, being too tender to bear its own weight. In fact, it is the expansion of the optic nerve, the immediate seat of vision. To see it well, an eye should be taken to pieces in a tumbler of water.

Explanation of Figure 3.

from dissection of a human eye, the organ being represented of the proper size.

a — The *optic nerve*.

bb — The *Sclerotic coat* cut and turned outward.

c — A circular portion of the *Sclerotica*, being a rim of the *white* of the eye, cut, and turned upward, having in its embrace the *cornea*.

d — The *cornea*.

ee — One half the *iris*, in its place, the other half being removed.

f — The *Pupil*, soon to be described, with the *crystalline lens* in its place.

g — The *Ciliary circle*, or second vertical partition, within the eye, behind the *iris*.

h h — *Choroid coat*.

i — The *Ciliary processes*, or ruffle like plaits of the ciliary circle, yet to be explained. A small portion of the *iris* is cut away to show them.

k — A portion of the *iris* cut and turned back.

l — The floating points of the *ciliary processes*, also turned back.

m — The middle smooth part of the *retina*, seen by cutting a hole through the *choroid coat*.

n — The roots of the *ciliary processes*, to which the black paint, secreted by the tapetum or inner surface of the *choroides*, adheres.

o — The *ciliary processes* inserted into the *capsule* or sack which contains the *crystalline lens*.

FIG. 3.

THE CORNEA.

Anteriorly, that clear, shining wall, resembling a watch crystal, which finishes the membranous box, is called the *cornea*. Simple as this thin crystal appears, it is infinitely curious in structure. It is made of thin, pellucid plates, one over another, held together by a spongy elastic substance. By maceration in water, a few hours, the sponge will absorb it, to such a degree, that the plates

may be distinctly felt to slide upon each other, between the thumb and finger.

Little glands, like bags of oil, only to be seen by the most powerful microscope, are lodged under the first plate, which are continually oozing out their contents upon the surface, which gives the sparkling brilliancy to this part of the eye. As death approaches, this fluid forms a pellicle, like a dark cloud, over the lower portion of the cornea. This formation is taken to be a sure indication of approaching dissolution. Many diseases are peculiar to the cornea; such, for example, as a milky colored effusion of matter under the external plate, preventing a free transmission of light to the interior. See fig. 2, letter *d*, and fig. 3, letters *c* and *d*, for representations of the *cornea*.

IRIS.

By looking into a person's eye, there seems to be a vertical partition, either black, blue, or hazle, as the case may be, which prevents us from looking into the concealed regions beyond, — having a round hole in its centre. Scientifically, this partition is called the *iris*, while its central orifice is denominated the *pupil*. How the diameter of this hole is enlarged or diminished, anatomists have never been fortunate enough to explain, satisfactorily, the apparatus is so minute, that they cannot decide upon its true character. One fact, however, is certain, that the pupil is large or small, according to the quantity of light that may be necessary to the formation of a distinct picture of the object seen, — and this change is effected without our being conscious of the action. Resembling other delicate membranes, in many respects, we are unwilling to confuse the subject with a description that would distract the mind of a new beginner.

From the reflection of such rays as are not admitted through the pupil, or central hole, we account for much of the lively brilliancy of the iris. On its back side it is rather fleecy, like the tapetum, but dissimilar in other respects. Over this is spread a black, blue, hazle, or tea-colored paint, which gives a permanent color to the eye. It has been often remarked, that the eyes and hair ordi-

narily correspond in color. Whenever the iris acts, as for instance, it does, in going from a dark, into a light room, the pupil is made smaller, — acting uniformly in its fibres, to keep it circular. On returning to the dark apartment, the pupil enlarges again. A knowledge of this fact, will explain the reason of a painful sensation in the eye, caused by a strong and sudden light. As soon as the iris has had time to diminish the size of its pupil, we can endure the same luminous object with perfect comfort. When we leave a well lighted room, on first going into a dark street, everything appears lurid and indistinct. The iris soon begins to enlarge the pupil, to admit more light, and when that has been accomplished, although in comparative darkness, we recognise objects without an effort. Acting independently of the will, its duties are like those of a faithful sentinel, always consulting the safety of the splendid optical instrument confided to its care, with reference to its subserviency to the being for whose use it was exclusively constructed. Were it otherwise, — were it left to our own care, how often it would be neglected, and indeed, totally ruined, solely for the want of undivided attention. All that complex system of machinery, on which life and existence are constantly depending, (the vital organs,) are wisely placed beyond the reach of the laws of volition. If the pulsation of the heart, the function of the lungs, or the circulation of blood in the brain, depended upon our attention, — our recollection of the fact, that they must be kept in motion, or we could not live, we should be in great danger of forgetting it, and therefore die in our first slumber !

Parrots have a voluntary control over the pupil, opening and closing it at pleasure. How this is done, or why, in the constitution of that bird, it is necessary, we cannot determine. Cats, also, appear to have a similar power of moderating or graduating the quantity of light, admitted into their eyes, as it suits their own convenience.

In carnivorous quadrupeds, the pupil is commonly oval, and oblique, permitting them to look from the bottom to the top of a tree, without much elevation of their heads. Graminivorous quadrupeds have an oblong pupil, placed horizontally, with respect to the natural position of the

body. This form gives them the faculty of surveying the expanse of a field, at once. Farmers are familiar with the circumstance that the ox, without being obliged to undergo the fatigue of circuitous marches, walks directly to the best feed in the whole lot, provided the enclosure be a plain. See fig. 3, letters *ee*, and *k*. Fig. 4, letters *cc*.

CILIARY PROCESSES.

Ciliary Processes. Directly behind the iris, is a second curtain, having a central hole through it, corresponding with that through the first curtain, but nearly as large as the whole diameter of the lens. All the luminous rays which are converged by the convexity of the cornea, which is, in effect, a plane convex lense, cannot enter through the pupil; many of them strike the plane of the iris, and are reflected back, as on a looking-glass, without penetrating its substance. If any rays were to get through, by such an irregular process, it would produce great confusion, by destroying the outline and vividness of the image previously made on the visual nerve, through the natural opening. To prevent such mishaps, the paint on the back of the iris is to absorb such rays as are not reflected, and have a tendency therefore to pass onward. Nature, as though fearful that circumstances might so alter the condition of the pigment,* as that some light, notwithstanding this precaution, might penetrate, has interposed this second veil,—solely it is supposed to stop all wandering rays. This ciliary curtain presents three thicknesses, and lastly has a thick coat of black paint on its back. In order to give it treble security, as it regards thickness, it is plaited like the folds of a ruffle. There are seventy folds in the human eye, of equal width, nicely laid, one over the other. A part so highly important, cannot be overlooked in studying the philosophy of vision.

* Pigment—*paint*.

FIG. 4.

Explanation of Figure 4.

This plan presents a longitudinal section of the left eye and bony orbit.

a—The upper eye-lid, shut.

b—The *cornea*.

cc—The cut edges of the *iris*.

d—The *pupil* or round hole through the centre of the *iris*, which, in the living eye, resembles a black, highly polished dot.

ee—The cut edges of the *sclerotic* and *choroid* tunics, with the *retina*, before exhibited in the preceding drawings.

f—The *crystalline lens*, as it is lodged, with reference to other parts.

gg—The *Ciliary processes* continued from the *choroid coat*. The plaits are here distinctly seen. In other designs accompanying this article, they will be noticed in a front view.

h—The *optic nerve* running from the brain, through the bones, to the globe of the eye, apparently closely embraced by the *recti*, or straight muscles.

i—The *levator*, or muscle that raises the upper eye-lid.

k—The upper straight muscle of the eye, called *levator oculi*.

l—Inferior straight muscles, its antagonist, on the under side of the ball, called *depressor oculi*.

m—A section of the inferior oblique muscle, called *obliquus inferior*, used in rolling the eye upward and inward, as in looking at a button laid above the root of the nose. The *superior oblique*, passing through a loop, carries the eye downward and outward, as in looking at the top of the shoulder. These two muscles, by old writers, were termed *rotatores* and *amatores*, in allusion to their office of rolling the ball and expressing passions.

nn—A section of the blood vessels and nerves, with a large quantity of fat, surrounding the *optic nerve*. This fat lies between the muscles and betwixt the socket and globe.

HUMORS OF THE EYE.

By humors, medical writers mean the fluids which distend the eye-ball. They are three in number, — possessing different densities, and varying much in quality, quantity and use. Beside fulfilling the first intention, — viz., distension, they are so purely transparent, as to offer no obstruction to the free passage of light. Too much care cannot be bestowed on the anatomy of these fluids by surgeons, as they are the seats of many remarkable diseases. Those only interested in this description, as general philosophers, by close examination, will have a perfect idea of them, and will consequently understand the real nature of some of the many causes that weaken the power of vision, or ultimately produce a total blindness. The gratification afforded by the examination of a bullock's eye, — tracing the several parts by this paper, will be an ample compensation for the labor, because it will forever fix on the mind interesting discoveries, and lead the reader, insensibly, to a course of reflections, productive of much intellectual enjoyment.

AQUEOUS HUMOR.*

The aqueous humor is the first in the order of demonstration, lying directly back of the cornea, — so clear, that one unacquainted with the existence of it, would not suspect a fluid there. In volume, it is far less than the others: it keeps the cornea prominent, always at the same distance from the iris, in the early periods of life. The space occupied by the aqueous humor, is called the *anterior chamber* of the eye. (See fig. 2, letter *f*.) Passing freely through the pupil, it also fills an exceedingly thin apartment, the circumference of the iris, called the *posterior chamber*. Thus it will be comprehended, that the iris, or in familiar language, first curtain, is actually suspended and floating in a liquor. Were it not for such a contrivance, the iris would soon become dry and shrivelled, by the intensity of the sun, and therefore rendered totally unfit to perform its appropriate office of opening

* Aqueous — *like water*.

and closing the pupil. An opinion is current, founded undoubtedly in truth, that the aqueous humor is never suffered to remain long at a time, but, on the contrary, is constantly poured in and again drawn off by an infinite number of invisible ducts. By being stationary, it would become speedily turbid, and finally lose its transparency. A knowledge of the rapidity of the secretion, has been the means of encouraging oculists to undertake novel methods of extracting cataracts, a kind of dark mote, through the cornea, as the most certain mode of restoring sight. Twentyfour hours after drawing off the aqueous humor, by a puncture, the anterior chamber will be full again.

Old age, characterized by a gradual decay in the vigor of all the individual organs, shows also its insidious approach in the eye. Vessels that have toiled with untiring diligence to the meridian of life, begin to show a loss of energy. Those which have carried the new, pure liquid, forward a less quantity in a given time than formerly, — while those whose task it was to convey away the old stock, are dilatory in the performance of their work. Hence, from being kept too long in the reservoir, in consequence of a tendency to become more turbid, does not allow the light to pass with former facility to the nerve: elderly persons, therefore, have indistinct vision from this cause, similar to looking through a smoky atmosphere. The writer has a favorite Newfoundland dog, whose eyesight is impaired in this way. Fishes have no aqueous humor at all, as it could be of no service in the element in which they swim: — the water surrounding them is the aqueous humor to their organs. Kept, as the humor is, in its own capsule, gives other advantages to the apparatus of vision: it is a concavo-convex glass, absolutely and indispensably requisite in an instrument that will produce an image by the same laws that govern the human eye. A sensible diminution in the quantity of this fluid, is very apparent in people advanced in years: the cornea becomes flatter; the segment of the transparent cornea is so altered, that rays of light are no longer converged as in younger days. This, together with corresponding derangements within the globe, constitutes

the long-sightedness of old age, — mechanically overcome by wearing convex spectacles. So gradually are the changes wrought by age, that glasses of different focal distances are sought from time to time, to keep pace with the progress of decay.

The ingenuity of man is nowhere more curiously displayed, than in thus availing himself of his discovery of the laws of refraction, in producing artificial lenses to gratify his eye, a never failing source of enjoyment, long after nature has begun to draw the blind that will ultimately close between him and the world forever.

CRYSTALLINE LENS.*

As magnifying glasses of different refractive powers give perfection to optical apparatus, so it is with respect to the lenses within the ball. The coats of the eye are equivalent to the tubes of such ingenious instruments. By *crystalline lens*, is simply meant a body like a button, resembling pure flint glass, somewhat of the shape of a common sun glass, convex on both sides. Its posterior convexity is greater than its anterior, — thereby bringing the rays to a point a little distance behind it. Careful investigation shows that this lens is made of a series of plates, applied to each other like the coats of an onion: the centre is firmer than the edges or space between the nucleus and margin.

As a whole, it possesses a highly refractive property, but in different degrees, according to the thickness of the lens, — receding from the centre to the circumference. Over the whole, to keep it from sliding in any direction, that the centre may not get without the axis of vision, is an envelope, having connexion with all the coats, where they are united on the borders of the cornea, and where it joins the white part of the eye. Being equally transparent with the lens itself, it cannot be conveniently exhibited. One of its properties is elasticity, though not to the extent we should at first view be led to imagine from the following remarks.

Cataracts, the most frequent cause of blindness, origi-

* *Crystalline lens*, — resembling crystal or glass.

nate in the lens; sometimes half way between the centre and margin, but ordinarily in the centre. They are either a peculiar deposition of opaque or milky matter, entirely preventing the ingress of light, or an opacity of some of the internal layers of plates, equally destructive to vision. Nothing short of the actual introduction of the couching needle within the globe, or a knife, promises any hope of recovery. Many children are born with this affection; at all ages, they are liable to form: perhaps the habit of gazing habitually on a strongly reflecting surface, may have a tendency to generate the disease. To remove cataracts by extraction, the operator slides a sharp, thin knife, resembling a lancet, through the cornea, from one side to the other, cutting one half from its natural attachment — leaving it, when the knife comes out, in the form of a flap, thus:

FIG. 5.

Explanation of Figure 5.

This plan represents an eye, surrounded by its natural appendages with a knife passing through the anterior chamber of the eye. A dotted line indicates the lower edge of the flap, made by cutting off just one half the cornea from its attachment with the sclerotica, in order to allow the crystalline lens to escape, whenever the knife is withdrawn.

As a matter of course, the aqueous humor escapes in a twinkling, at the same moment, the capsule of the lens, previously ruptured, designedly, by the point of the knife, as it slides along, spasmodically acts upon the lens by spontaneous contraction, and protrudes it through the wound. Undoubtedly, the grasp which the straight muscles have on the ball, accelerates its escape.

Thus, in taking away the obstruction to sight, the whole lens is extracted. Perhaps the question may arise

—how the eye is to answer its original design with the loss of one of its important glasses?

To *couch*, an operation often mentioned, and often performed, is to thrust a delicate needle through the white of the eye, just on its border, till the point reaches the lens, which is then depressed into the lower part of the eye, below the optic axis, so that light may, by entering the pupil, arrive at the nerve. In this last operation, fears are always entertained, that the lens may rise again to its former position, rendering a repetition of the operation indispensable. *Secondary cataracts* sometimes form, after couching or extraction, and arise in consequence of a thickening and opacity of the capsule, which is left behind. Such cases are more alarming in their progress than a disease of the lens, as no surgeon is warranted in promising even a partial relief. If he attempted to tear away the membrane, he might also rend every other within the globe.

A few facts of this kind which have a practical bearing, more or less interesting to every person, may lead to correct views, in relation to some of the diseases which are common to this curious, wonder-working organ.

Explanation of Figure 6.

This is a scheme showing how a bad operator, by introducing the couching needle too near the cornea, may rupture the ciliary processes, and actually divide the lens in two pieces, without moving it from the optic axis.

A — The *vitreous humor*.

B — The *lens*.

CC — *Ciliary processes*, torn by the lower part of the needle, thereby doing great violence and a permanent injury to the organ.

DD — The *iris*.

E — The anterior chamber of the aqueous humor.

Explanation of Figure 7.

This figure represents the mode, and, in fact, the place into which the couching needle is introduced, in the operation of couching.

A—The pupil is seen through the transparent cornea.

B—The iris.

C—The needle, with the handle elevated so as to depress the point.

D—The lens and point of the needle in outline: this precisely represents the position of the lens after couching. To complete the operation, it must be carried a little back before withdrawing the needle.

FIG. 7.

VITREOUS HUMOR.

Beyond the two humors we have been describing, is the third, differing essentially from either of them. In the first place, in volume it far exceeds the others,—occupying more than two thirds of the whole interior and posterior of the ball. Its consistence is that of the white of an egg, but kept in its place by its own appropriate capsule; it presents many interesting phenomena. When the sack is punctured with a pin, it flows out slowly, in consequence of its adhesiveness. Like the preceding humors, it is transparent, allowing the free passage of light through its substance, and also possesses the additional quality of allowing the rays to separate again, as they leave the point at which they were converged, just back of the lens. Observation proves that the vitreous humor is kept in place by being lodged in cells. Perhaps a piece of sponge might give a tolerable idea of the cellular structure, admitting it to be as transparent as the water which it absorbs. On its fore part, it has a depression, in which the posterior convexity of the lens is lodged,—as represented in this diagram. Concave, therefore, in front, and convex behind, gives another kind of optical glass, known as the *meniscus*,—the crescent, faintly resembling the first quarter of the new moon. If

by accident, or a want of skill, the operator suffer this humor to escape, in any of his operations, the globe at once diminishes in size, and all hope of the restoration of a diseased eye is lost. The small mistake of pricking the sack containing the vitreous humor, will decide whether the patient is to live in never ending night.

FIG. 8.

Explanation of Figure 8.

One dotted line, indicates, in this diagram, the aqueous humor; another the iris, and a third the lens, and the fourth the vitreous humor. Let it be remembered that all the space between the back side of the lens and optic nerve, is filled completely, with the glairy, vitreous humor, the third fluid, and inmost of the eye.

OPTIC NERVE.

Any person possessing an ordinary share of curiosity, can examine the *optic nerve*, or nerve of sight, at leisure, in slaughter houses, fish markets, and in fowls. In the human eye, — perhaps, to be clearly understood, outside the eye, as it extends to meet the brain, it is like a cotton cord, larger than a wheat straw, of a mealy whiteness, not far from three quarters of an inch in length. Arising from the substance of the brain, it traverses the bony canal till it reaches the back of the eye-ball; as soon as it arrives in contact, as it were, it is suddenly divided into innumerable filaments, which wend their way into the globe, through very minute holes. From a fanciful resemblance to a sieve, this spot on the sclerotic, is called the *cribriform* plate. When the threads have emerged within, they assume another form, by expanding into a web, constituting a third or inmost box. Some believe the nerve is spread on a thin, *unseen* membrane, in the form of a highly organized nervous paste. Here, on this pulp, having considerable range of surface, is the sole seat of vision. A vulgar opinion presupposes some exceedingly acute nervous point, — the exquisite

point of vision. Nothing, however, is more absurd; vision includes considerable surface. In the centre of the substance of the nerve, an artery penetrates the eye, accompanying the *filaments*, to nourish the humors. When the cornea has been cut away, and the iris detached, this vessel may be distinguished, of a bright scarlet, spreading its hair-like branches about, like the limbs of a tree. The nerves which give sensation to the eye, connecting it with the system, may be noticed, as previously remarked, lying between the two first coats. The optic nerve conveys to the mind the sensation of the existence of things, as perceived by the eye, while the *commands* of the same mind are conveyed to it by these little threads of nerves, so insignificant, as to be often overlooked in a dissection made purposely for them.

FIG. 9.

Explanation of Figure 9.

In this figure, the *cornea* is cut away, and the *sclerotic* dissected back. This is a beautiful and easily accomplished dissection. In a bullock's eye all these delicate nerves can be readily displayed. A pair of sharp pointed scissors and a few pins, to hold parts to a board, are the proper instruments. Even in schools, ladies could exhibit most of this beautiful optical apparatus.

- a* — The *optic nerve*.
b — The *sclerotic coat* turned back, so as to show the vessels of the *choroid coat*.
cc — The *ciliary nerves*, seen piercing the *sclerotic coat*, and passing forward to be distributed to the *iris*. The *iris*, so highly organized, is not supplied by any nervous influence from the *optic*, but by the hair-like nerves, here displayed, creeping to its margin between the two exterior coats.
d — A small nerve passing from the same source to the same termination, but giving off no visible branches.
ee — Two *venæ vorticosæ*, or whirling *veins*, so denominated, because they seem to fall into shapes, resembling falling jets of water; these return the blood from the eye, sent in by its central and other arteries.
f — A point of the *sclerotic*, through which the trunk of one of the veins has passed.
g — A lesser vein.
h — The point, or circular point of union, where all the coats of the eye, together with the cornea and iris, seem to be glued firmly together.
i — The *iris*.
k — The *straight fibres of the iris*.
l — A circle of fibres or vessels, which divide the iris into the larger circle *k* — and the lesser one *m*.
m — This letter points to the lesser circle of the *iris*.
n — The fibres of the lesser circle.
o — The pupil.

PIGMENTUM NIGRUM.*

Lastly, to complete the internal structure, and fit it for the performance of its destined office, the inside surface of the second coat, *choroides*, is thoroughly painted black. In the order of explanation, this paint is just behind the retina. When the humors have been taken out the pigment is readily examined. The use of it is very obvious; viz., to absorb any aberrating or unnecessary rays of light, which confuse the vision; or destroy the intensity of the impression on the nervous expansion of the retina, — and indeed, to *suffocate* them entirely.

JUNICA CONJUNCTIVA.

Posteriorly, the eye, by its long cord of optic nerve, seems to rest on one extremity of an axle; — the opposite in front, being the skin, passing over the eye, as it comes

*Pigmentum Nigrum — *black paint*

down from the forehead, to join the cheek. To comprehend, clearly, the manner in which the eye is fastened, before,—observe how the skin turns over the edge of the lid, going about three quarters of an inch back, striking the ball to which it is made fast, then folded back upon itself, adhering to the whole anterior surface of the cornea,—dipping down and finally mounting over the margin of the lower lid, and ultimately losing itself on the face. As we cannot recognise this, on a living eye, it will at once lead one to suppose it is as clear as glass, which is the case. Streaks of blood, when the eye is inflamed, lie covered over by the tunica conjunctiva. Now if particles of sand, or other irritating substances get under either eye-lid, they cannot possibly enter but little way, before reaching the duplication of this transparent skin ; there is no danger, therefore ; the offending matter cannot get so far between the socket and ball, backward, as to abridge the free motion of the organ, or do a permanent injury to the parts. This partition, or doubling over of the conjunctiva, is a curious provision, as we are thereby enabled to reach the source of irritation. The principle of introducing eye-stones, to extract foreign matter, is this, and not owing, as vulgarly supposed, to the crawling about of a smooth piece of sulphate of lime, on some forty or fifty feet. The stone is so much larger than the extraneous body, already there, that it excites a proportionably larger quantity of tears, to wash it away : in essence, therefore, we submit to a greater temporary evil, to get rid of a lesser one. Precisely on this principle, a person chewing tobacco, is constantly spitting : the vile weed is so offensive to the nerves about the region of the throat and tongue,—a stimulant so unnatural and uncongenial to the constitution of the body, that the saliva is poured out, with increasing copiousness, to wash it from the mouth.

Serpents annually shed their skins, which, unaccountable as it at first appears, are whole over the holes where the eyes were. That thin sheet, so very clear and fine in texture, is the conjunctiva, showing its origin,—hence a similar origin may safely be inferred over other eyes.

Every species of animal with which naturalists are conversant, possess this defensive transparent membrane.

MEMBRANA NICTITANS.

A third eye-lid is given such animals as are destitute of hands, or are incapacitated, by the arrangement of their limbs, from reaching their eyes. This is called *membrana nictitans*, — and a more striking piece of mechanism, there is not in existence. It slides from one angle of the eye to the opposite one, under the first pair of lids, — and that, too, whether the others are open or shut, being totally independent of them in muscular action. Its use cannot be mistaken : it is on purpose for clearing away matter that may be irritating to the eye. Any extraneous substance is brushed from the cornea in an instant, by the broad sweep of the night lid. Birds that seek their food in the night, as owls, defend their irritable organs, through the glare of daylight, by drawing over this singular curtain. Dogs, cats, foxes, wolves, bears, lions, tigers, &c, can each of them, by this brush, remove the minutest mote from the cornea, more expeditiously than any oculist on the globe.

TEARS.

Perfection is everywhere observed in animal mechanics. The eye would soon become a useless instrument, notwithstanding the nice adjustment of its several parts, were it not for the external apparatus of eye-lids, glands and tears, whose combined action keeps it always in a condition to be useful. Were not the cornea frequently moistened, it would become dry and shrivelled. To obviate this, a sack of fluid is fixed just under the edge of the orbit, above the eye-ball, which is continually pouring out its contents by the pressure and rolling of the eye. Flowing through numberless apertures, it washes the crystal, and finally passing into grooves, on the inner margin of both eye-lids, runs to their terminations in a small pin-like orifice, at the inner angles. To keep them open, a hoop is set in the mouth of this lachrymal duct. This, too, can be shown by turning the lid outward by the finger. Finally, the tears are conveyed into the nose

through a bony tube, answering the double purpose of softening and keeping moist the living membrane, on which the sense of smell depends. On both eye-lids, at the roots of the eye-lashes, are in each, a row of glands, equivalent to bags, smaller than pin heads, which ooze out an oily secretion, to prevent the adhesion of them together, as is sometimes the case when the eyes are much inflamed. Surely such manifest provision for contingencies, and for the preservation of this one piece of mechanism, indicates Super-human contrivance.

Explanation of Figure 10.

FIG. 10.

This plan exhibits the natural size of the passages of the tears.

a—Is the lacrymal gland, or in other words, the organ that secretes the tears; showing its natural situation, with respect to the eye-lids.

bb—The eye-lids, widely opened.

c—The situation of the *puncta lacrymalia*, or the holes, at the inner angles of the lids, through which the tears flow, to get into the tube which finally conveys the fluid to the nose.

dd—The ducts continued from the *puncta lacrymalia*.

ee—The angles which the ducts form after leaving the puncta.

f—The termination of the lacrymal ducts in *gg*.

gg—The lacrymal sac.

h—The nasal duct, continued from the lacrymal sac.

ON SEEING AT A DISTANCE.

When we speak of the distance to which vision extends, we can understand either the sphere of distinct vision, or of seeing in general. The latter has a much larger semi-diameter than the former; and the series for the one is in animals different from that of the other. The extent of distinct vision, is pretty nearly in relation with the distance of the lens from the retina in the axis of the eye. But the power of seeing at a distance, depends, in gene-

ral, in land animals, on the absolute magnitude of the semi-diameter of the external surface of the cornea. The larger this is, the greater is the number of rays that reach from distant objects through the cornea to the interior of the eye, and the more easily are such objects rendered visible. But this applies to land animals only. The cornea has no such value in aquatic animals, in arresting the rays of light, as that the limits of vision can be determined by it. If we arrange land animals and birds according to the measure of their power of seeing in the distance, we obtain the following series :

Horse - - - -	73	Rough-legged Falon -	32
Ox - - - -	66	Buzzard - - -	28
Asiatic Elephant - -	65	Night-Heron - - -	27
Antelope Rupicapra	64	Short-eared Owl -	27
Lynx - - - -	55	Psittacus Aracanga -	25
Kangaroo - - -	50	Turkey - - -	25
Wolf - - - -	45	Tame Swan - - -	23
Fox - - - -	38	Ardea stellaris - -	22
Man - - - -	34	Carrion Crow - -	22
Simia Inuus - -	30	Tarrocks - - -	20
Hystrix cristata - -	30	Green Woodpecker -	19
Marmot - - -	28	Corvus glandarius -	17
Brown Bear - - -	27	Yellow Oriole - - -	15
Otter - - - -	26	Psittacus rufirostris	11
Ursus Lotor - - -	25	Virginian Opossum -	20
Simia Capucina -	24	Common Squirrel -	19
Beaver - - - -	23	Badger - - - -	19
Polecat - - - -	23	Cavia Cobaya - - -	18
Horned Owl - - -	56	Water Rat - - - -	14
Ostrich - - - -	50	Hamster - - - -	12
Golden Eagle - - -	40	Long-eared Bat - -	4
Stork - - - -	33	Crossbill - - - -	9

In this table the larger animals, in general, are those that see farthest. But there are exceptions to this rule. It is worthy of remark, that birds which, in the distinct vision of a point, precede quadrupeds of similar magnitude, are inferior to them in distant vision, and that man agrees with birds in this respect. Thus the great owl, (*Strix Bubo*), ostrich, and golden eagle, excel in the

first point; in the latter are inferior to the ox, elephant, &c. The chamois and the Lynx, and many other animals, have a wider power of vision than man, in which the radius of the sphere of distinct vision is much smaller than in him.

This conclusion is contrary to the generally received opinion on the subject. Birds, and particularly rapacious birds, are considered as having a much greater power of distant vision than most quadrupeds; and many will be disposed to challenge the fact, that the ox possesses this power in an equally high, or even higher degree. But when we consider fairly the experience on this subject, we shall find that it is not in opposition to what has just been stated. Mayer found in his experiments on the acuteness of vision, that, in seeing, it depends not only on the illumination of the object, and its distance from the eye, but also on the relation of the object and the eye to the neighborhood. But it is quite otherwise with birds which look from above, downwards, or with quadrupeds, whose vision is directed upwards or forwards. No one has measured the great distance at which a far-seeing bird perceives its prey; and indeed it will always be difficult to do this with accuracy. But Treviranus remarks, 'I doubt not, if we possessed certain observation on this point, that the greatest distance would not exceed that of a far-seeing man.

When, for example, Faber, in proof of the sharpness of the sight of birds, remarks, 'the high flying eagle or the kite perceive the motions of small animals on the ground; the solan sees a very small fish from a considerable height; and gulls, terns, rapacious gulls, (*Lestri*,) and petrels, fly from all sides to a particular point, where an object is seen floating on water; he presents us with data which are far from being satisfactory. When, on the contrary, Ross affirms, in his voyage to Baffin's Bay, that he obtained certain data, proving that the power of vision of man over the surface of the sea extended to 150 English miles, it is conceivable that the farthest seeing bird could not exceed this. But experience would seem to show, that birds, although in general their power of distant vision is not very great, that they possess a very *sharp sight*

in a greater distance than most quadrupeds. There are many curious observations illustrative of what we have just said. He says, he threw, at a considerable distance from a throstle or mavis (*Turdus musicus*) a few small beetles, of a pale gray color, which the unassisted human eye could not discover, yet the throstle observed them immediately, and devoured them. The long tail titmouse (*Parus Cordatus*) flits with great quickness among the branches of trees, and finds on the very smooth bark its particular food. When we examine the spots where it stops for food, nothing is perceived by the naked eye, although minute insects are visible by means of the magnifying glass. A very tame redbreast (*Sylvia rebecula*) discovered from the height of the branch where it usually sat, at the distance of eighteen feet, small crumbs of bread spread out on the ground, the instant they were thrown down; and this, by bending its head to one side, and therefore using only one eye. A quail, at the same distance, discovered, by the use of only one eye, some poppy seeds.

A REASON WHY PERSONS IN ADVANCED LIFE, REQUIRE
CONVEX GLASSES.

Age gradually relaxes the tension of the whole system; the eye, therefore, suffers in a corresponding ratio. The cornea becomes less prominent:—the convexity of the lens is also diminished, and the rays of light are consequently less convergent than formerly. The picture of the object is faint, because the rays have a tendency, by their divergency, to impinge at a supposable plane, beyond the retina.

FIG. 11.

Explanation of Figure 11.

In this figure is represented the effect of old age on the humors: without the intervention of the glass A, the rays have

a direction which would form the image at some distance beyond the *retina*, as at B. But, by the convex glass A, which, for example, is the spectacle worn by aged people, the *direction* of the rays of light is so corrected, that the image falls accurately on the bottom of the eye, or *retina*.

When the convex lens is interposed between the eye and object, as represented in the above diagram, the rays are made more converging, — so that the picture strikes exactly and distinctly on the nerve. People slide their spectacles on the nose unconsciously till the true focus is procured.

A REASON WHY NEAR-SIGHTED PERSONS SEE INDISTINCTLY.

Either the crystalline lens, but more generally the cornea, is too prominent — converging the light too suddenly ; — that is, converging the luminous rays at an unnatural place within the vitreous humor. An indistinct outline of the object is the effect of their great divergency, after decussating — before they arrive at the retina. The following diagrams will illustrate the subject far better than a whole volume of written explanations.

FIG. 12.

Explanation of Figure 12.

In this figure, the convexity of the cornea, or the focal powers of the lens, being too great for the length of the axis of the eye, the image is formed at A, before the rays reach the surface of the *retina*, or inner box, illustrated in Fig. 2, letter c ; and after coming accurately to the point, they again begin to diverge ; which diverging rays, striking the surface of the retina, give the indistinct vision of the near-sighted individual. But as this indistinctness of vision proceeds from no opacity, but only the disproportion of the convexity of the eye to the diameter, the defect is corrected by a concave glass, represented in the next figure.

Concave glasses are the restoratives of the near-sighted eye, by separating the rays, and carrying the image so

far back as to place it on the retina. Old age, the destruction of the first eye, eventually restores the near-sighted, by the gradual flattening of the cornea, till at threescore and ten, such persons can see clearly and distinctly without artificial aid. Many near-sighted people totally ruin the organ by prematurely wearing glasses, as a focus is established which neither glasses can keep pace with in age, nor age thoroughly overcome.

FIG. 13

Explanation of Figure 13.

The effect of this glass being exactly the reverse of the convex, it causes the rays to fall upon the surface of the eye, so far diverging from the perpendicular line, as to correct the too great convergence, caused by the convexity of the humors. When a near-sighted person has brought the object near enough to the eye to see it distinctly, he sees more minutely and consequently more clearly; because he sees the object, says Mr Bell, larger, and as a person with a common eye does, when assisted with a magnifying glass. A near-sighted person sees distant objects indistinctly, and, as the eye, in consequence, rests, says the same observing writer, with less accuracy upon surrounding objects, the piercing look of the eye is very much diminished; and it has, moreover, a dulness and heaviness of aspect. Again, the near-sighted person knits his eyebrows, and half closes the eye-lids; this he does unconsciously, to change the direction of the rays, and to correct the inaccuracy of the image. Near-sighted people have but little expression; the countenance loses all its majesty, by habitually wearing glasses.

THE IMAGE OF AN OBJECT IN THE EYE, IS INVERTED.

Rays of light going from the upper and lower points of an object, are refracted towards the perpendicular; that is, bent out of the course which they have a tendency to run, by the crystalline lens behind, where they unite in a point, — and, then crossing, diverge again. Here then, the image is bottom upward, as will be noticed in the preceding diagrams by the arrow, and its image on the retina. Decussation is indispensable to the vision of things. An object could not be represented on a point;

there must be surface to create an image on, and by the laws of optics, the representation of the object, without an additional glass within the eye, must necessarily be as it is.

HOW THE OBJECT APPEARS IN ITS TRUE POSITION, THE
IMAGE BEING INVERTED.

Habit is supposed to be the cause of seeing objects as they really exist, in relation to surrounding bodies.* A few philosophers conceive that the mind contemplates the object only, without reference to its representative on the retina, which is made there as a natural result. Certain it is, that without the image, there is no vision. How the brain is operated upon by the light that defines the object, will probably never be known. The minuteness of the miniature traced on the retina, precisely like the object in every minute particular, is truly astonishing. By cutting off the coats of a bullock's eye, and holding a clean white paper near, this beautiful exhibition can be leisurely observed. If a sheet of white cotton cloth, six feet square, is elevated 24,000 feet in the air, the eye being supposed one inch in diameter, the miniature of the sail on the retina will be only one eight thousandth part of an inch square; which is equivalent to the 666th part of a line,—being only the 66th part of the width of a common hair! Leaving this point to philosophers, we proceed to such facts as are susceptible of positive demonstration.

HOW, WITH BOTH EYES, ONLY ONE OBJECT IS SEEN.

At one side of the centre of each eye, there is a surface more susceptible of visual impressions than any other. These points correspond in both eyes—being precisely on the two retinas alike. An impression therefore on one, provided the light strikes them equally, produces precisely the same effect on both. This, instead

* A Dr Reed, of Cork, has recently attempted to demonstrate that the *cornea* is the true seat of vision, and that we see by means of erect and reflected, and not by refracted and inverted images.

of making vexation, gives strength or greater vividness, as the images are on surfaces of the same structure, transmitting, through the two optic nerves, the same idea, or that indescribable something that creates an idea. The optic axes, spoken of in the books, by this explanation, will be understood. If one eye is distorted,—pushed by the finger one side, when we are in the act of contemplating an object, it will appear double, but less distinct in the one so distorted. The rationale is this; viz. the visual surface on which the image is made, so exactly alike in both eyes, as to call up but one idea, being forced out of the optic axis, the rays still make the picture, but on a surface, less highly organized,—that does not correspond with the surface on that retina which has not been disturbed. The two images have now different localities. No course of experiments are more within the reach of those who have the desire to experiment, than these.*

* Generally the eyes of insects are of two kinds; viz. simple and compound, having the appearance of two crescents, making the largest part of the head, and containing an infinite number of little hexagonal protuberances, convex, and placed in lines. The number of lenses in one eye, vary in different insects. Hooke computed those in the eye of the *tabanus* or horse-fly, to amount to nearly 7000. Loewenhoeek found in that of the *libellula*, (dragon-fly) 12,544; and 17,325 have been counted in a common butterfly; the picture of an object, impinged on their retinas, must be millions and millions of times smaller than in the human eye. Some insects have a still more curious apparatus of vision; three small spherical protuberances rise from the top of the head, and are eyes, in addition to the ordinary ones on the side of the head. They are solely for seeing distant objects; the first, for near ones. Loewenhoeek looked through the eye of a dragon-fly with a microscope, as a telescope, and viewed the steeple of a church, which was 299 feet high and 750 feet distant. He plainly saw the steeple, though it did not appear larger than the point of a very fine needle. He also viewed a house and could distinguish the front, discern the doors and windows, and moreover, perceive whether they were open or shut. The writer has recently seen the light strongly reflected from the eye of the bee-moth, which precisely resembled the ground faces of a stone in a watch seal. This, therefore, was a multiplying eye. Several insects present the same structure, but nature's object is not understood by entomologists.

FIG. 14.

Explanation of Figure 14.

In this figure, B, B, the eyes, having their axes directed to A, will see the object C, double, somewhere near the outline D, D. Because the line of the direction of the rays from C, do not strike the retina in the same relation to the axis A, B, in both eyes. If a candle is placed at the distance of ten feet, and I hold my finger at arm's length, between the eye and the candle, when I look at the candle, my finger appears double, and when I look at the finger, the candle is double.

FIG. 15.

Explanation of Figure 15.

A is exactly in the centre of the axes of both eyes; consequently it is distinctly seen, and it also appears single, because the form of it strikes upon the points of the retina, opposite to the pupils in both eyes. Those points, as before remarked, have a correspondence, and the object, instead of appearing double, is only strengthened in the liveliness of the image. Again, the object B will be seen fainter, but single and correct. It will appear fainter, because there is only one spot in each eye, which possesses the degree of sensibility necessary to perfect vision: thus, it will be understood, the object will appear single, as the rays of light proceeding from it have exactly the same relation to the centre of the retinæ, in both eyes.

THE REASONS WHY CROSS-EYED PERSONS SEE ONLY WITH ONE EYE.

With such as have a permanent squint, (cross-eye,) only one eye is attended to, though they may not be apprehensive of the fact. From continued neglect, the distorted organ wanders farther and farther from the axis

of vision, till it finally becomes totally useless: hence one is doubtful, at times, which way the cross-eyed person is looking, from a want of parallelism in the motions of the eyes. When the wandering eye is exclusively attended to, the vision appears unimpaired. The image is well painted in the natural one, but weak in the other, solely because the place of the image does not correspond with the place of the image in the first. The mind, instinctively, therefore, is devoted to the eye that gives the liveliest impression, to the entire neglect of its aberrating fellow.

THE REASON WHY THE PUPILS OF AN ALBINO'S EYES
ARE RED.

If a person is born without the *pigmentum nigrum*,—heretofore defined to be a paint to suffocate all unnecessary light, as it goes through the retina, after the image is formed,—the blood vessels of which the *tunica choroides* or second coat is made, are not hidden. Consequently, they show through the transparent humors, like a sparkling red gem, the size of the diameter of the pupil. If a delicate brush could be inserted to give it a black coat of paint, the eye would appear as others do. Such persons can see better in a weak light than in broad day, because the brightness of the sun's light dazzles, and produces a tremulous motion in the whole organ. As an evidence that this redness is caused by the blood in the vessels, after death, when it coagulates, the redness, in a great measure, disappears. White rabbits, white mice, brought in cages from China, besides a vast variety of birds, have no pigment on the *choroides*, and are therefore distinguished for red pupils. The existence of the *pigmentum nigrum*, is a concomitant of a day-seeing eye. In man, the want of it, constituting the albino, is an anomaly.

A morbid action of the absorbents sometimes removes the paint, and the pupil, to the surprise of observers, becomes scarlet. A partial absorption of it is often the cause of a diminution of the original powers of vision: under such circumstances, the pupil assumes a bronze hue, accompanied by a debility and tremor of the globe under the influence of a moderate degree of light.

The writer remembers an accomplished female albino, who publicly exhibited herself in Boston, several years since. An exact wax figure of the lady with the 'red eyes,' belongs to a group, now in exhibition at the New England Museum. About the same period, the writer also recollects of seeing a white negress, who was an albino. Her father and mother were of the jet black color, though she had a pale, deadly white complexion. The hair of both these albinos was silky and milk white.

THE REASON WHY MANY ANIMALS SEE IN THE DARK.

Owls, fishes, cats, bats, &c, instead of the pigmentum nigrum, have a silvery paint of a metallic lustre, where others have the black paint, which operates like a mirror, in reflecting the light from point to point, within the eye, illuminating it till its concentration excites the retina to perceive. When viewing a cat's eyes in the remote part of a dark room, there are certain positions, in which they are seen by the observer, by the reflected light within themselves, as though they were phosphorescent: their brilliancy is very peculiar. Upon the principle of a looking-glass behind the retina, all the night-prowling animals are qualified for seeing with those few rays of light, which the constitution of their eyes is formed for collecting in the dark. By daylight, they perceive objects, as man does in the dark, viz. indistinctly. Nature is remarkably economical in the use of matter which enters into the composition of animal bodies. If a man be kept a long time in a perfectly dark room, the pigmentum nigrum is taken away; but a compensation is given him, for he can then see as perfectly in the dark, as he could before in the light. On the other hand, the paint is deposited again when he is restored to the light of day. This point has been decided in the persons of state prisoners kept in the dungeons of European despots.

Is there any arrangement in the eye, and what is it, by which animals that see in the dark are enabled to make up for the want of external light? When we consider the metallic lustre of the tapetum, which in many animals occupies a great part of the choroid coat, or even its whole surface; farther, its resemblance to a concave mirror, and its relation to the light that penetrates into

the interior of the eye, we cannot help considering it as the means employed for this purpose, by its collecting the light and illuminating, by its reflection, objects lying in the axis of the eye. Prevost objects to this explanation, that there are many animals whose eyes have no tapetum, although they conduct themselves as if they saw in the dark. This is actually the case. The tapetum occurs in *carnivora*, *ruminantia*, *pachydermata*, *cetacea*, *owls*, *crocodiles*, *snakes*, *rays* and *sharks*: it is wanting in *apes*, *glires*, *chiroptera*, *hedgehogs* and *moles*; in *birds*, with the exception of *owls*, and in *osseous fishes*. But the *gnawers* or *glires*, *bats*, the *hedgehog* and *mole*, are animals that obtain their food more by night than during the day; and many of them conduct themselves in the deepest darkness, as if they were directed by the sense of sight. But this objection may be obviated, by remarking, that it is probably some other sense than that of vision, which procures for many of these animals sensations of external objects in the dark. We have in favor of this opinion, not only the experiments of Spallanzani on *bats*, from which it appears that, after these creatures were deprived of the use of their eyes, they conducted themselves as if they still possessed the power of vision, but also the examples of species of that family, in which the eyes are so imperfectly developed, or lie so much concealed behind the outer skin, that they are of little or no use to the animal. The genera that see in the dark, have undoubtedly so irritable a retina, that they can only see during a very feeble light; whereas in those animals whose eyes are organized equally for daylight and nocturnal darkness, the retina possesses less irritability. Hence, although these are without a tapetum, it does not follow that this organic part does not afford a mean for seeing during a feeble light.

The tapetum is either spread over the whole choroid, or only over the upper half of it. The first is the case with the *cetacea*, *owls*, and with those *amphibia* and *fishes* which are provided with this shining envelope; the second occurs in *carnivorous* and *ruminating* animals. It is more extended in the *ruminating* than in the *carnivorous* tribes. But it always extends so far as to encompass the posterior extremity of the internal ocular axis. All

the rays of light from external objects which reach it, are united on it, through the transparent part of the eye, and it again reflects back the whole united rays towards the lens. This latter unites them into a single cone, which has the ocular axis as its axis, and its point is directed outwards. The very convergent rays of this cone become more divergent by their passage from the lens into the aqueous fluid, and from this into air or water. Finally, the apex of this cone falls into the point of most distinct vision; for in this point is situated the focus of all the rays that reach from the interior of the eye to the posterior surface of the lens. The cone is complete when the tapetum is spread over the whole of the choroid; but the upper half of it is wanting, when it occupies only the upper hemisphere of the coat. The tapetum is confined to the upper half of the choroid in all animals, whose residence and manner of life are of such a nature, that the under half of the retina is immediately struck by bright daylight, and for this simple reason, because the animal must have been dazzled by the reflection of the bright light from the under half of the latter. It covers the whole posterior portion of the internal eye in the cetacea and owls, many amphibia, rays, and sharks, because these animals live constantly in the water, or in a feebly luminous medium, or have their place of residence in dark corners, or go in quest of food during the night. The experiments and observations of Prevost and Esser, detailed in 1826 and 1827, show that the reflection of light from the tapetum is the cause of the luminousness of the eyes, observed under certain circumstances in the twilight, in cats, dogs, sheep, and in general in all the animals having a tapetum. But whether or not a phosphoric light sometimes proceeds from the retina or choroid, has not as yet been fully ascertained. There are many examples of a luminousness in the dark having been observed in the human eye.

THE REASON WHY FISHES CANNOT SEE IN AIR AS WELL AS
IN WATER.

When the rays of light pass from a rarer to a denser medium, as from air into the aqueous humor of the eye, they are refracted towards the perpendicular. Now the

fish has but a drop, as it were, of aqueous humor, and, moreover, the light arrives at its eyes through the whole body of water above. The light is refracted only in a small degree in entering its eye, because the humor is of the same density of the fluid through which the light is transmitted. The cornea is quite flat; if it were prominent, like the human eye, the sphere of vision would be too circumscribed;—but by giving a prominence to the whole, and placing the crystalline lens in the fore part of the eye, they have a long diameter,—and with the provision of a large pupil, are completely fitted to see in the element in which they are destined to live. With an eye of this description, they must necessarily see in air, as other animals see in water.

Those animals whose eyes are organized for seeing in water, see but indifferently in air. Hence, in those cases where the habits of the animal require it to see in both *media*, it is provided with two sets of eyes, or with eyes accommodated for seeing in each element. Thus the *Gyrinus natator*, an insect which generally swims on the surface of water, but half submerged, is provided on each side with two eyes, one pair situated on the crown of the head, for seeing in the air, and another pair under the head, for seeing in the water. It is also probable that the fish named *Cobitis anableps*, which has in each eye an upper and under cornea of different curvatures, and for each cornea a particular anterior surface of the lens, is capable of seeing in water with the one half of the eye, and in air with the other half. Thus *Sæmmering* found in this fish, the semi-diameter of the upper cornea—1,0; the under 1,2; the two curvatures of the upper part of the lens—0,5; and the two curvatures of the under part of it—0,2 Paris lines. It cannot be denied, that, in general, land animals can see under water, and aquatic animals in air; even man sees under water, although the contrary has been maintained. It is not, however, possible, that the same eye is ever so organized as to see equally well in both elements. Land animals always see indifferently in water, and aquatic animals imperfectly in air. The one is long-sighted in water, and the other short-sighted in air. An animal in which the eye is

adapted for seeing equally well in air and water, can have but imperfect vision in either. These conclusions are in conformity with what is known of the power of vision in those animals that live partly on the land and partly in the water. The seal (phoca) is one of those animals that live in both elements. But the seal has but imperfect vision in the air. Rosenthal in his memoir on the organs of the senses of seals, says, 'we have convinced ourselves by careful observation with living seals, of the species *Phoca Grypus* of Faber, that the animal is always short-sighted in the air; for when we held before it fish and other bodies, as pieces of wood or stones, it did not distinguish them accurately, until they were brought so near, that the organ of smell could be called into activity. I have the most satisfactory evidence of the short-sightedness of seals, from a series of experiments and observations, made in Boston harbor. My duties requiring me to be floating in a boat, from vessel to vessel, many months of the year, I have been so often accompanied by seals, alongside and astern, as to establish the fact, that they can see but a few yards in the air, and then very obscurely. Scoresby remarks, 'Whales are observed to discover one another, in clear water, when under the surface, at an amazing distance. When at the surface, however, they do not see far.' *Scoresby's Arctic Regions*, vol. i. p. 456. Faber, in his very interesting work on the habits and manners of birds that inhabit high northern latitudes, remarks that Divers (*Colymbus*) do not see so well above water as Grebes (*Podiceps*), but better under water, because it is there they obtain their food.

It also appears, that birds which see well in one element, do not see so well in the other. Faber proposes the question, 'Is it the case that divers, when under water, draw their nictitating membrane over the eye, as they do when looking towards the sun, in order to prevent the contact of the water?' It would appear, from the observations of Treviranus, from whose excellent work, the observations on vision we are now detailing are principally extracted, that, by drawing the nictitating membrane over the eye, divers, and all other land animals which seek their food under water, are enabled, not only

to prevent the immediate action of the water on the eye, but also to discover their prey. But as the light loses more of its power on passing through water, than in passing through air, and is still more weakened in its progress through the nictitating membrane, it follows that owing to this membrane, vision must be less distinct under the water than in the air.

THE REASON WHY MAN CANNOT SEE UNDER WATER.

A man under water, sees objects as a very aged person sees through a concave glass, placed close to the eye. The fish is long-sighted under water and man is short-sighted. If he uses spectacles, whose convexity is just double the convexity—or equal in convexity on both sides to the cornea of his own eye, he will see under water. The necessity of this is obvious; the aqueous humor is of the same density with the water, and there cannot, therefore, be any refraction of the rays in passing from the water into the land-seeing eye.

Euclid and other distinguished ancients, contended, and, indeed, supposed that vision was occasioned by the emission of rays from the eye to the object. He thought it more natural to suppose that an animate substance gave an emanation, than that the inanimate body did. In 1560, the opinion that the rays entered the eye, was established. Kepler, in 1600, showed, geometrically, how the rays were refracted through all the humors, so as to form a distinct picture on the retina; and he also demonstrated the effect of glasses on the eyes.

IN WHAT MANNER DOES THE EYE ADAPT ITSELF TO THE DISTANCE OF OBJECTS?

No one has satisfactorily answered this question. One philosopher supposes the eye is at rest, when we examine a distant object, as a mountain, the spire of a church, or a landscape, but, that in the act of seeing near objects, there is an effort. It has been supposed that this effort is the action of the straight or *recti muscles*, exhibited in the first plan of the cordage of the eye, compressing the globe, so equally, as to elongate the eye, and lengthen the axis, so much, as to favor the union of the pencils of

rays on the sensible retina. This could not take place in many aquatic animals, in whose eyes the sclerotica is perfect bone. Another opinion is, that the eye is at rest in looking at near objects, and laboring, when viewing things at a distance. One writer is of the opinion that the iris contracts, and so draws the circular margin of the cornea, towards the pupil, as to make it more or less convex, according to circumstances. A great variety of experiments have been instituted, to determine, accurately, whether there really is any change made in the length of the axis of the eyeball or not, but none of them can be certainly relied upon. A favorite theory has had its advocates, that the crystalline lens has an inherent power of altering its degree of convexity, and thus accommodates the eye to all distances. Of all the absurd hypotheses on the subject under consideration, this is decidedly the most objectionable, in the estimation of an anatomist. The truth is, an action takes place in the eye, in adapting itself to near and distant objects, which depends on that vital property of a living system which no theory can reach, and which the deductions of human philosophy can never with certainty explain.

Having now completed this very brief and imperfect sketch, of the mechanism and philosophy of the eye, condensed from manuscript observations, which from the peculiar nature of my studies, have been continually accumulating, I leave it with regret, conscious of its defects,—although a hope is entertained that it will serve to excite an additional interest in this department of science, and thus accomplish one of the principal designs of the series to which it belongs.

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SCIENTIFIC TRACTS.

NUMBER VI.

HEAT.

INTRODUCTION.

IF the indispensable utility of any branch of science, constitutes a sufficient reason for its universal dissemination among the great mass of our people, a knowledge of the nature and effects of *heat*, would seem to claim a pre-eminence over all the various branches, which in the philanthropic spirit of the day, it is deemed highly necessary to disseminate among our farmers, mechanics, and laborers, as essential to their comfort, happiness and success in their various callings.

Heat animates, vivifies, and adorns the animal part of creation; it brings forth, embellishes, and matures the vegetable world; it contributes in a very great degree to the domestic comforts of man — but few of the arts and trades are carried on without the aid of this important agent. It is by the agency of heat, that stone and brick are prepared for the builder's hand; the ship cannot be built without its assistance; and whether she perform her distant journeys by the aid of steam or wind, both are produced by the same cause. In fine, there is no occupation of man, in which the laws of heat may not enlighten and aid him in the prosecution of his labors.

All mankind receive heat and light from the sun, all feel the genial influence of these blessings; and yet how few understand the peculiar laws by which the effects are produced. The laws and effects of heat are less studied than many other more difficult branches of science; and yet what wonderful effects have been produced on the civilization of the human race by the elucidation and application of its laws. The steam engine is a proud monument of the triumph of learning and research over

ignorance. The invention of this highly useful addition to the power of man, is owing entirely to the elucidation of the laws and effects of this principle.

Most men are familiar with some of the most common effects of heat, as they are exhibited in the course of every day life; and yet there is but a small number who extend their inquiries beyond this—and a still less number who inquire into the *why* and *wherefore*, of these apparently simple effects. Believing, therefore, that it is highly useful to men to understand and comprehend what they have learned by experience; knowing that such knowledge is highly pleasing, particularly to such as are conscious of possessing the rich gift of an inquiring mind, we propose to explain in a concise and elementary manner, the effects and properties of heat, together with some of its most important applications in the arts of life.

EFFECTS OF HEAT.

One of the first, and most common effects of heat upon all bodies, whether solids, fluids or airs, is to expand them, which may be shown by the following

Experiment.—Fit a rod of iron to a hole in some metallic plate; if it exactly fits when cold, when heated it will be so enlarged as not to enter it.

The same will be found to be the case with almost all solid bodies. But all solids do not expand equally by the same heat. Lead expands more than any other solid, while glass expands the least. Numerous experiments have been made by different philosophers, on the expansion of solid bodies by heat, from which the following conclusions are derived.

A metal that has been condensed by hammering or wire-drawing, expands more than when in a looser state; and those metals which melt the easiest, generally expand the most.

Advantage is taken of this property of solids, in many of the arts and trades. Wheels are tired with iron which, when cold, is a little smaller than the wheel; and by being heated it expands, and is thus placed upon the wheel, after which it contracts by cooling, and thus binds all the parts of the wheel firmly together. Large casks and butts for brewers, &c., are rendered tight and secure by placing hot iron or copper hoops upon them which, by

contraction on cooling, bind the staves together. Advantage is also taken of this property, in the construction of nice clocks and watches. As the pendulums of clocks and the balance-wheels of watches, are made of metal which expands by heat, and contracts by cold, the length of them is altered by heat, and this of course alters the rate of going: if a pendulum rod which vibrates seconds be lengthened one hundredth part of an inch, the clock will lose ten seconds in twentyfour hours, and if it be shortened, it will cause the clock to go proportionably faster. Several ingenious contrivances have been found out for remedying these defects. The most common of which is, what is called the *gridiron* pendulum, which is formed of five bars, three of steel and two of a compound of zinc and silver; these are so arranged that the expansion of the steel is counteracted by the expansion of the zinc and silver, by which the pendulum is always of the same length. The balance-wheels of watches are constructed upon the same principles.

The great force with which metals expand when heated, was applied some years since in a singular and novel manner at Paris. The two side walls of a building, which were of stone, having been pressed out by the weight of the floors and roof, several holes were made in the walls opposite to each other; through these, strong bars of iron were placed, their ends projecting outside of the walls, large plates of iron were screwed on to them. The bars were then heated, which of course lengthened them, by which the large plates could be advanced, and when the bars cooled, the walls were drawn together. The same process being repeated several times, the walls were drawn to their original position.

Liquids are expanded more by heat than solids, and airs more than liquids. The expansion of liquids by heat, is easily shown by experiment. Place a quantity of water in a common Florence oil flask, sufficient to fill it to the neck; mark the point at which it stands when cold, then apply heat; in a short time it will be seen that the water is above the mark. The same will apply to almost all liquids.

Those liquids expand most by the addition of a certain quantity of heat, which boil with the least heat. Thus mercury, (*quicksilver*,) expands less than water, by

equal additions of heat; and water boils with less heat than mercury; and for the same reason, alcohol (*spirits of wine*) expands more than water.

The nearer a liquid is to boiling, the more it expands, and of course, the further it is from boiling, the less it expands by the addition of a certain quantity of heat. The expansion of liquids therefore, does not depend on their density, but upon the quantity of heat necessary to make them boil; and no reason can be given why different liquids require different degrees of heat to make them boil.

The expansion of liquids by heat, and contraction by cold, has furnished us with the means of measuring the relative heat or temperature of all other bodies. This is done with an instrument called a *Thermometer*. It is almost unnecessary for us to describe a Thermometer. It consists essentially of a glass tube, with a bulb or hollow ball at one end, which is filled with mercury which, after the air has been expelled by making the mercury boil, is sealed up air tight. When this instrument is exposed to heat, the mercury expands, and of course, rises in the tube; and when exposed to cold, the contrary takes place. To this tube a scale is attached for the purpose of comparison; this scale is graduated and marked, by plunging the tube and bulb into melting ice; the point at which the mercury then stands, is called the freezing point of water. It is then plunged into boiling water, the point at which the mercury stands is called the boiling point of water. However often we perform these operations we shall find that the mercury will always stand at the same point; hence we learn, that snow or ice always begins to melt at the same temperature, and that water boils always at the same degree of heat. Mercury is used for thermometers, because it expands more equally than any other liquid, owing to the great distance between its freezing and boiling points; quicksilver boils at 660° of Fahrenheit, and freezes at 40° below zero; so that there is 700° between the two points.

There are many kinds of thermometers, which derive their names from their inventors. Thus Fahrenheit's* thermometer, which is used in Britain and her posses-

* Wherever, the degrees of heat are mentioned in this tract, it is intended to refer to Fahrenheit's scale.

sions, Holland, and the United States, has its zero placed at 32° below the freezing point of water, and the boiling point of water at 212° ; of course, the distance between the freezing and boiling points, is divided into 180 parts. Celsius' thermometer, otherwise called the Centigrade thermometer, is used in Sweden and France; and the space between the freezing and boiling points is divided into 100° ; the freezing point of water is marked 0. Reaumer's, or in truth, Deluc's thermometer, which was formerly used in France, has its freezing point marked 0, and boiling point 80° . De Lisle's thermometer is used in Russia, and has its space between the freezing and boiling points divided into 150 parts, the zero being placed at the boiling point, and 150 at the freezing point.

All gaseous bodies are expanded by heat, as air, carbonic acid gas, (*fixed air, dead air,*) which may be shown by the following

Experiment. — Take a glass tube with a bulb at one end and open at the other, plunge the open end into water, then apply the heat of a lamp to the bulb; bubbles will be produced from the end under the water, which is owing to the escape of air from the tube; of course the air has been expanded by the heat.

The expansion of gaseous bodies differs essentially from that of solids or liquids, as they all undergo the same expansion by the same additions of heat. The steam of water expands just as much as air, when the same addition of heat is made. Air by being heated from 32° to 212° , increases more than one third in bulk.

This difference in the expansion of different bodies, arises from the difference in the cohesive force by which their particles are bound together — in solids the force of cohesion is great — in liquids it is less, and in gaseous bodies it is nothing. Therefore, in the expansion of bodies by heat, there is more force to be overcome in solids than in liquids; more in water than in air; consequently air expands more than any solid or liquid body.

The expansive force of steam is applied to the use of man, in that magnificent production of human ingenuity, the Steam Engine, a description of which would be out of place in this treatise.

We have already stated, that there are a few excep-

tions to the expansion of bodies by heat; a few bodies expand when at a certain temperature, either by an increase or decrease of heat.

Water is the most singular and important instance of this effect: this liquid decreases in bulk until it has cooled to a certain point, and then increases just as if heat were applied. The temperature at which water has the greatest density, is at about 40° of Fahrenheit, at which point it expands either by heat or cold.

The expansive force of water in the act of freezing, is practically known to almost every person in our climate. Water left in earthen or glass vessels, during cold weather, expands in freezing, and breaks the vessel. Pipes for conducting water are often burst, by water freezing in them. The pavement stones of our streets are often observed during fall and winter to be raised out of their places, which is caused by the freezing of the water beneath them. The earth around rocks and stones is often observed to be separated from them, which is frequently supposed to arise from the rocks and stones sinking, which, in truth, is caused by the water in the earth, which freezes and expands, while the rock does not expand, but diminishes in a small degree only. Rocks are rent asunder, trees are split by this property of water. This agency of water is a striking instance of the Divine goodness, in causing rocks and soils to moulder to powder, thereby fitting them well for the purposes of the husbandman.

If it were not for this property of water, our rivers and brooks would in the course of our winters, become entirely solid, which of course, would destroy their innumerable inhabitants; the seas and oceans of the polar regions of the earth would become one entire mass of ice, because the ice as soon as formed on the surface, would sink to the bottom, and another layer would be formed, and sink also; in this way the whole would be frozen.

The writer of this tract has burst an iron bomb shell, 7 inches in diameter and nearly 1 inch thick, by the freezing of water. Some Venetian philosophers burst a brass globe one inch in diameter by freezing water in it, which it was calculated, was equal to a force of 27,720 pounds.

The expansion of water in the act of freezing, is sup-

posed to be owing to the tendency which water has in becoming solid, to arrange its particles in one determinate manner, so as to form prismatic crystals.

Some of the metals have the property, when in a liquid or melted state, of expanding when they become solid; these are cast-iron, bismuth, and antimony. Hence the use of cast-iron in making castings of a perfect shape, because the iron in the act of cooling, expands and completely fills the mould. Hence likewise, the use of antimony in the composition of types. It should be remembered however, that these bodies do not constitute an exception to the law of expansion by heat, because the expansion in the above metals is owing to the change of state, from a liquid to a solid, that is, to crystallization. All bodies do not, however, expand on changing their state from a liquid to a solid. When liquids become solids they either form crystals or an irregular mass, in which there is no regular arrangement. In the former case, expansion takes place, in the latter contraction. Water and the different kinds of salts are instances of the former; oils and tallow are examples of the latter.

Nearly all solid bodies may, by heat, be converted into liquids, and all liquids may be converted into solids by a sufficient degree of cold. Again, all liquids may be converted into vapor or elastic fluids, by heat; and a great number of elastic fluids may, by cold, be condensed into liquids: hence the state of a body depends essentially upon the temperature in which it is placed.

The following table exhibits the temperature at which a number of bodies melt.

Cast Iron	-	-	-	20577°	of Fahrenheit.
Plate Glass	-	-	-	17197	"
Fine Gold	-	-	-	5237	"
Fine Silver	-	-	-	4717	"
Lead	-	-	-	594	"
Bees' Wax	-	-	-	142	"
Spermaceti	-	-	-	133	"
Tallow	-	-	-	92	"

Water freezes at 32°, yet it may by care and a particular process, be cooled down to 22°, without becoming

ice. When water is thus cooled down, the least agitation causes it to become ice instantaneously.

Any kind of salt dissolved in water, lowers its freezing point. Hence, sea water does not freeze so soon as fresh water.

OF THE CAUSE OF HEAT.

There are many natural agencies, the causes of which remain unknown at the present day, and probably always will. Learned men have been unremitting in their investigations for ages, to discover the hidden causes of natural phenomena, but in many cases without effect, among which is the cause of heat. Philosophers and learned men have, as yet, been unable to determine whether heat is caused by a peculiar subtile fluid which enters into, and is expelled from bodies, and thus produces the sensation of heat or cold; or whether the cause is owing to a motion of the particles of the body, vibratory or rotatory. There have been numerous arguments adduced in support of both suppositions, all of which, however, are inconclusive; and as our object is rather to explain the laws and effects of heat, than to deal with ingenious theories, we shall omit any detailed account of the arguments and experiments in favor of either.

OF THE MOTION OF HEAT.

When we hold our hand near a piece of hot iron we feel the sensation of heat, which is caused by the heat of the iron flying off in all directions, in the same manner as sparks fly from heated iron when hammered upon the anvil. This peculiar motion of heat is called *radiation*.

When we hold a piece of iron with one end of it in the fire, and the other in the hand, that part of the iron which is in the hand will in time become hot; which is in consequence of the heat being *conducted* through the iron, from one end to the other: this property of heat is called *conduction*.

Radiation. — Every person must have observed that when a hot body is exposed to the air, that it cools in a short time, and that bodies do not cool in the same time; now is this difference owing to the form or dimensions of the body? or the nature or color of its surface? the answers to these questions lead to some highly important *practical* results.

Experiment. — Take two tin or Britannia tumblers, and cover the outside of one of them with lamp-black, fill them both with boiling hot water, and place a thermometer in each; it will be seen that the water in the coated tumbler will cool to the temperature of the room in about one half of the time required to cool that in the bright one. The same effect will be observed whatever be the nature of the metallic bodies, whether the tumblers be iron or silver, provided their surfaces have the same polish as the tin, and coated in the same manner.

The metals radiate heat less than any other substances. Glass radiates $7\frac{1}{2}$ times more heat than polished tin.

Mr Leslie found that the surface of a body produced the greatest effect upon radiation when the air was still; and that in a strong wind the polished and coated vessels filled with hot water cooled in nearly the same time. This proves that the lamp-black does not *conduct* the heat off, but *radiates* it. The shape of a vessel has no effect upon the radiating power of a body, except that the greater the surface with the same solid contents, the greater the radiation.

The *color* has but a slight effect upon radiation. If instead of coating the tumbler with lamp-black, we cover it with white paper, nearly the same effect is produced — it therefore depends mainly upon the nature of the *surface*.

The following substances radiate heat in the order in which they are placed. Lamp-black—writing paper—glass—tarnished lead—bright lead—polished iron—tin plate—silver—gold—copper—polished brass.

Bright metallic bodies cool the slowest; culinary utensils, therefore, which are required to keep whatever is in them hot, should be of metal, with bright clean surfaces. For the same reason, pipes, which are used to conduct heat from a furnace to an apartment, should be made of bright metal. Stove pipes and others, which are used to heat apartments by distributing the heat, should be covered with lamp-black, or some other similar substance, which will cause them to radiate more heat. And for the same reasons, such vessels as are intended to receive heat, should be black, as they heat much sooner than they would if bright; of course, such culinary vessels should not be scoured on the outside, where the heat comes to them. Heat is reflected in the same manner as

light, having the angle of incidence equal to the angle of reflection; that is, if heat strike a surface, it flies off from it at the same inclination with which it struck it.

Experiment.—Take two common metallic lamp reflectors, place them a short distance apart, with a hot iron ball in the focus of one, and a thermometer in the focus of the other; the thermometer will immediately begin to rise, in consequence of the heat from the ball being radiated to its reflector, from whence it is thrown to the other reflector, and from thence it is reflected to its focus, in which the thermometer is placed.

If a pane of glass be held between the reflectors, the thermometer does not rise; this proves that the heat does not proceed directly from the ball to the thermometer, which is further shown by removing the reflector nearest to the ball, as the thermometer will then fall.

From numerous experiments, it has been shown, that those surfaces which radiate heat best, are the worst reflectors; while those which radiate least, are the best reflectors; metals, consequently, are the best reflectors, and when polished better than when tarnished. This is the reason that brass andirons, which are very near the fire, are but little heated; because brass is one of the poorest radiators, and one of the best reflectors. Advantage is taken of this property, in the culinary operation of roasting with a tin kitchen, where the heat is reflected upon the spit.

Radiation and reflection do not take place under water. Radiation is considerably retarded by interposing a screen before the hot body; a piece of pine board, one inch thick, is not so effectual in stopping radiating heat as a piece of gold leaf $\frac{1}{30000}$ part of an inch thick. Those substances which radiate best, intercept the least of it, and *vice versa*. Hence, those substances which absorb the least heat, are the best interceptors of it. Therefore, ladies' screens should not be made of paper, or similar substances, but of some bright metallic substance. Fine wire, polished, and woven fine, would stop heat more effectually than paper.

Conduction.—If we take several pieces of different substances, such as silver, copper, iron, lead, and glass, of the same size, and place a coat of wax upon one end of each, then place the other ends in the same heat, it

will be perceived that the wax does not begin to melt on them all at the same time. That on the silver will melt first, and that on the glass last. Therefore, some bodies heat sooner than others. When bodies become hot in this manner, it is said to be *conducted* through them.

All solid bodies are conductors of heat. The metals are the best conductors, next come stony substances. When a solid is sufficiently heated to change its state, it is no longer a conductor. Ice will conduct heat at any temperature below the freezing point of water, but at 32° it is no longer a conductor; because any addition of heat changes it to water.

In solids, the heat moves from particle to particle, but not in liquids and gaseous bodies; because their particles move freely among themselves. As we have explained in a former chapter, bodies are increased in bulk by heat, and are of course lighter; therefore, when heat is applied to a liquid, it heats a stratum of it next the source of heat, and it becomes lighter, and if below another, it will rise, while another takes its place, and in this way, the whole becomes heated: of course, it makes a great difference to what part of a liquid we apply the heat. If we apply it to the top, it can make its way downward but slowly, in the same way solids are heated; but if it be applied at the bottom, it makes its way upward, in consequence of the movement of the particles, independent of any conducting power. Liquids then, have the power of *carrying heat*.

Experiment.—If we mix some light substance, of the same specific gravity of water, with a portion of this liquid in a glass tube, or oil flask, and heat be applied to it, the particles will be seen in motion; in the middle of the tube they will be seen to *ascend*, and near the sides to *descend*. These motions are caused by the heated particles going to the sides and giving out heat, thus becoming heavier, they fall to the bottom, and push up lighter ones, which, in their turn, lose a part of their heat, and fall also. Upon this experiment, and similar ones, Count Rumford founded this general rule: the more the internal motions of a liquid are impeded, the longer time does it require to heat them to any given temperature.

Liquors are but slight conductors of heat.

As before mentioned, the metals are the best conductors of heat ; next come stony substances ; some of which are, however, better conductors than others. Bricks are worse conductors of heat than stones, except some varieties of sand stone ; brick houses, therefore, are warmer in winter, and cooler in summer, than stone houses.

Glass is a bad conductor of heat ; this causes it to break when suddenly heated, in consequence of one surface being expanded before the other can become heated so as to expand also. Cold, of course, produces the same effect by contracting one surface before the other can have parted with its heat. Glass tumblers which have thick sides and bottoms, are very liable to break when hot liquids are poured into them, for the same reason. The purer the glass the less liable it is to break, because it is more compact, and therefore expands more equally. For the same reason crockeryware is liable to be broken. Hence also, the practice of glass manufacturers, who place the ware after it is blown and shaped, in a hot oven to cool gradually. This is called *annealing*.

Dried woods and charcoal are very bad conductors of heat ; hence the use of the latter in making instruments for keeping provisions, &c, in hot weather, called refrigerators. Dried bass-wood has only about four times as much conducting power as water. Pitch-pine, and spruce are better conductors than white pine.

Count Rumford made numerous experiments on the conducting power of the different substances which are used for clothing. He found that the worst conductors were hare's fur, and eider down. Next came beaver, raw silk, ravellings of manufactured silk, wool, cotton, and linen lint, and the more open the texture of the substance, the worse conductor it was. For this reason blankets are warmer than full'd cloth of the same fineness ; eider down comfortables, than those made of cotton or wool. The warmest clothing is such as has the finest texture and the longest nap. All of these substances have a large quantity of air combined with them, and air being a bad conductor, the more air they contain among their parts the warmer they are.

There are numerous instances in the arts, where

advantage is taken of the property of bodies in conducting heat, — or, what is the same thing, in confining heat. The brick-maker covers his kilns of unburnt bricks with a coating of burnt bricks, plastered over with clay and sand to keep the heat in, these substances being bad conductors. Furnaces are coated with the same material, or with charcoal, which is much better. Double windows are to be seen in Boston during the winter season, the use of which is founded upon the same principles — the air which is confined between them being a bad conductor of heat, prevents the warm air of the room from being cooled from without.

Upon the same principles we may explain several phenomena which, although of daily occurrence, are but seldom understood. If we apply our hand in cold weather to wood, iron, or stone, the iron feels colder than the wood, and yet they have both been exposed to the same temperature, and of course if exposed to the thermometer, would both show the same degree of heat. The iron feels the coldest because, being the best conductor, it carries off the heat of the hand much faster than the wood, which is a bad conductor. For the same reason when iron and wood are heated to the same temperature before a fire or otherwise, the iron to the hand will feel much the hottest. Workmen who are exposed to great heat or cold, should always wear flannel, as it is a slow conductor of heat, and in cold weather will keep the heat of the body in, and in warm weather will keep the external heat out. For the same reason, woollen or worsted mittens, or gloves, are much warmer in winter and cooler in summer, than leather.

OF THE DISTRIBUTION OF HEAT.

Every person knows by experience the common law of heat, that a warm body cannot remain long near a colder one, without being deprived of a part of its heat, which passing to the colder one makes it warmer.

Experiment. — If we mix a quantity of water at 212° , with the same quantity at 32° , the mixture will be found to be 122° , which is the exact mean of the two; of course the hot water has lost 90° of its heat, while the cold water has gained 90° .

If any number of bodies at different temperatures be carried into a room, in a short time the air of the room and the different bodies will all be found to have the same temperature.

Sir Isaac Newton suggested the following law as to the heat lost, — ‘that in given small spaces of time the heat lost is always proportional to the heat remaining in the body;’ by which he calculated several temperatures above the scale of thermometers. This, however, has since been found strictly true only for temperatures below 212° ; for all above, it is only an approximation. The heat which is lost by a body in cooling is partly conducted away by the air, some of it is carried off by currents produced in the air surrounding the body, and some by radiation.

A hot body will of course heat that portion of the air which immediately surrounds it, which becoming light will rise while another portion of cold air takes its place, and in this way a current will be produced, which much accelerates the cooling of the body. It is evident that this current will be the stronger the higher the temperature of the body.

If these currents be artificially increased, of course the rate of cooling will be increased. Hence the effect of winds in cooling bodies. The rate of cooling is always proportional to the velocity of the current, or, if the body move, proportional to its velocity. Hence red hot balls which are fired from cannon, should not be fired with great velocities, or at great ranges.

OF FLUIDITY.

Dr Black was the first who explained in a satisfactory manner the cause of fluidity. He found that when a solid body was converted into a liquid, a certain quantity of heat combined with it, without sensibly increasing its temperature; and that this portion of heat is the cause of fluidity. When a fluid is converted into a solid, a certain quantity of heat leaves it without sensibly diminishing its temperature.

Experiment. — Take a pound of new fallen snow, and add to it a pound of water at 172° , the snow will be melted and the whole will be found to have a temperature

of 32° . Here, 140° of heat has left the water and combined with the snow, and thus caused it to melt; yet the water resulting from this melted snow has the same temperature as the snow. Therefore a pound of snow requires 140° of heat to melt it.

Water after being cooled down to 32° cannot freeze until it has parted with 140° of heat, and ice after being heated to 32° will not melt until it has absorbed 140° of heat; hence the slowness with which these operations are performed.

To the quantity of heat which thus combines with a body and causes fluidity, Dr Black gave the name of *latent heat*.

The fluidity of all bodies is owing to the same cause, and it may be considered as a general law, that whenever a solid is converted into a liquid, it combines with heat. Metals owe their ductility and malleability to the latent heat which they contain. Hence, we have the reason why they become hot and brittle by being hammered.

OF STEAM AND EVAPORATION.

Nearly every liquid body when raised to a certain temperature is gradually converted into an elastic fluid, which like air is invisible. Water when heated sufficiently is converted into an elastic fluid, called steam, which is invisible, and has the same mechanical properties as air. One cubic inch of water will make 1800 cubic inches of steam.

When a vessel of water is placed over a fire, the water gradually heats until it reaches 212° , after which its temperature will not increase; yet, heat must be gradually and constantly combining with it, and as it does not become hotter, it must combine with the steam which is constantly flying off; but the steam is only at 212° , of course the heat must become latent, and we must conclude that the change of water into steam is owing to this *latent heat*.

Steam is water combined with about 1000° of heat, therefore, as has been before shown, a given quantity of steam at 212° , will heat a great deal more water than an equal weight of water at 212° , because it contains a great deal more heat, which is given out by changing the steam into water.

The bubbling of water when boiling, is owing to the formation of steam, which rises continually from the bottom to the top of the vessel. At the common pressure of the air, near the level of the sea, water boils at 212° . The higher we carry water up the side of a mountain, the less heat is required to make it boil; because a part of the pressure of the atmosphere is removed. A difference of 1° in the boiling point of water corresponds to a difference in elevation of nearly 520 feet. The heavier the air is, the greater the pressure, and of course the more heat is required to make water boil. By increasing the pressure sufficiently, water may be heated to 400° without ebullition. The effect of pressure on the boiling of water, may be shown by this experiment. Take a common olive oil flask, fit a good cork to it, put about half a gill of water into it, and place it over a lamp until it boils. Permit the boiling to continue a short time, and then place the cork in the neck tight, and remove it from the lamp; the water will continue to boil a short time after. On plunging the flask into cold water, the boiling will again commence with violence. Remove the flask into hot water and the boiling will cease; and if it is again plunged into cold water, it will again boil.

The boiling of the water in this experiment, before the cork is placed in it, expels the air in the bottle, and steam takes its place; and the flask when removed from the lamp, becomes a little cooled, which condenses a portion of the steam, which removes some of the pressure, and thus causes the water still to boil. When the flask is plunged into cold water, more of the steam is condensed, and more of the pressure removed, which causes it to boil violently; and when the bottle is placed in warm water, a portion of steam is again formed, thereby increasing the pressure, and thus prevents the boiling — which pressure is again removed by plunging the flask into cold water, and thus causes the water again to boil.

Steam imparts its great heat so easily to bodies which are colder than itself, as to fit it peculiarly for many useful practical purposes in the arts and in domestic life. The heat produced by means of steam, for many purposes is preferable to the heat of fire. Dyers' and brewers' vats are much better heated by steam than in any other way.

Many colors are better and more economically prepared by steam than by fire. Vegetable extracts for medicinal purposes are best prepared by the heat of steam. For heating baths, steam is far cheaper than fire. Large or small apartments may be warmed by steam with cleanliness and great safety. All the culinary operations of boiling are better performed by steam than in any other way. In order to heat a liquid by steam, the vessel containing the liquid, should be placed in a larger one, making the open space between them steam tight, and the steam admitted into this space will raise 20 gallons of water at 52° , to 212° in eleven minutes.

One gallon of water made into steam will heat six gallons at 50° to the boiling point, or eighteen gallons from 50° to 100° .

It has been found that in warming large buildings, such as manufactories, one cubic foot of the boiler will heat 2000 cubic feet of space to 70° or 80° ; and that one square foot of surface of a steam pipe, will heat two hundred cubic feet of space. Cast-iron pipes are considered the best for heating apartments by steam, and should be covered with lampblack and placed near the floor, as the coldest air is always lowest.

Animal food is considered more nutritious and easier to digest, when prepared with steam, than when cooked in the usual method.

Evaporation.—When a liquid gradually assumes the form of an elastic vapor at all temperatures, it is said to *evaporate*; and as the temperature is increased, the evaporation is also increased. Likewise, as the pressure is diminished, the evaporation is increased.

The reason of evaporation is beautifully explained by the doctrine of *latent heat*. We have explained how liquids, in order to be converted into steam or vapor, require a large quantity of heat, which combines with them and becomes latent, and taking away this heat produces cold.

Experiment.—Place a watch glass with a small quantity of *ether* in it, in another glass containing a small quantity of water, and place them both under the receiver of an air-pump. Exhaust the receiver, and in a short time the *ether* will have disappeared, and the water will be frozen.

Here, removing the pressure, the ether evaporated, and deprived the water of its heat and it became frozen. Of course evaporation always produces cold.

It is owing to the evaporation of water, that showers in summer cool and refresh the earth, by the evaporation of the rain which is spread over its surface.

Many practical uses are made of this property. The natives of India wear moist cloths about their heads to keep them cool, which is done by the evaporation of the water. The same people preserve their apartments cool during the night, by hanging them with wet cloths. Wine-coolers produce their effect entirely by evaporation. Caravans which cross the hot deserts of Asia and Africa, carry earthen bottles filled with water, which is preserved cool by having the bottles wrapped around with wet cloths.

The effect of evaporation is of the greatest importance to man, in preserving the human body at a healthy temperature. The natural heat of the body is about 96° . Active exercise or exposure to great heat, raises the temperature of the body, which is unhealthy; but perspiration, brings a watery fluid to the surface, which by being evaporated, soon reduces the heat of the body to its healthy state.

Distillation.—Some liquids are more easily converted into vapor than others. If two liquids, which boil at different temperatures be mixed together, they may be again separated by exposing them to such a heat as will cause that which boils at the lowest temperature, to assume the state of vapor, which by being collected and condensed by cold, will form the original liquid, while the other is left in the vessel. This is the process in the distillation of all substances.

If the pressure of the atmosphere is removed from the substances to be distilled, the operation for some purposes is much better performed. Vinegar distilled in this way is perfectly pellucid and of an agreeable flavor, which it has not when distilled in the usual way.

OF COLD.

We have already explained, that when a body passes from a solid to a liquid state, it must absorb a large

quantity of heat, which produces cold. By applying this principle to the conversion of certain salts into liquids, an intense degree of cold may be produced. Thus by mixing two parts of snow with one part of muriate of soda, (common salt), a degree of cold 5° below zero may be produced. Dry potash, (carbonate of potash,) mixed with snow will produce cold 53° below zero.

The following table shows the proportions of different ingredients, and the degree of cold produced by mixing them together. In all cases the effect is produced by the sudden conversion of the solid salts into liquids.

Cold mixtures, produced without snow or ice.

Mixtures.	Parts.	Thermometer sinks.
Nitrate of Ammonia	1	} From 50° to 4° .
Water	1	
Sulphate of Soda (Glauber's Salt)	3	} " 50° to 10°
Diluted Nitric Acid (Aqua Fortis)	2	
Sulphate of Soda	8	} below zero.
Muriatic Acid (Spirit of Salt or Marine Acid)	5	
Phosphate of Soda	9	} " 50° to 21°
Nitrate of Ammonia	6	
Diluted Nitric Acid	4	

Cold mixtures with snow and ice.

Mixtures.	Parts.	Thermometer sinks.
Snow or pounded ice	3	} From 32° to 23° below 0.
Diluted Sulphuric acid, (oil of Vitriol,)	2	
Snow	4	} " 32° to 40° below 0.
Muriate of lime	5	
Snow	2	} " 32° to 50° below 0.
Crystallized muriate of lime	3	

If these materials are cooled down before they are mixed, by exposure to frigorific mixtures, a much greater degree of cold may be produced in some cases — thus, in the last mixture, in the above table, if the snow and muriate of lime be cooled down to 40° below zero, and then mixed, a cold of 73° below zero will be produced. The greatest degree of cold ever produced by artificial means, was 93° below zero.

Artificial cold is used in the preparation of some articles of luxury for the palate, and is often employed in philosophical experiments, as in freezing mercury, &c.

OF THE SOURCES OF HEAT.

The two principal sources of heat are, the sun, and combustion; there are others, but we shall confine our remarks to these. Heat is constantly radiating from the sun, and evolved or given out during the combustion or burning of bodies.

The vital part of our solar system is the sun, from this source we receive all the heat necessary for producing the fruits and flowers of our earth, which are matured and perfected by the light from the same body. We may behold the wisdom of that Power, that balanced the sun and planets in the heavens, displayed in an equal degree in the distribution of the animals and plants of our little planet, according to their respective natures, as far as respects heat and light. Those animals which are placed in the arctic regions, are all protected from the cold by a covering of fine fur, exactly adapted to keeping out the cold; while those of the tropics have a covering adapted to their climate — like the elephant, who has scarcely any covering.

It is not our purpose at present, to inquire into the cause of the immense quantity of heat and light which we constantly receive from the sun. Dr Herschel supposes it to be owing to luminous clouds, which float in the atmosphere of the sun, and as these clouds are subject to various changes, both in quantity and lustre, he accounts for the difference in the heat of different years.

When a piece of glass is exposed to the rays of the sun, it is not soon heated; but if a piece of iron, of the same thickness be exposed during the same time, it will soon become heated; in the same manner, all transparent bodies stop but few of the solar heating rays, while opaque bodies intercept more or less of them; and the darker the color of the opaque body, the more heat is intercepted. Hence, arises Dr Franklin's rules for the color of clothing. Black or dark colors during winter, and white or light colors for summer. But it is to be questioned whether these conclusions are correct. By a reference to

what we have said upon *radiation*, it will be seen, that dark colors radiate more heat than light ones: therefore, dark clothing carries off more of the heat of the body, than light colored would.

The heat produced by the direct rays of the sun upon a body, seldom exceeds 120° , but by a peculiar contrivance to prevent the heat from being carried off by the surrounding bodies 220° or 230° may be produced.

When the rays of the sun are concentrated, they produce a much greater effect, as with a burning glass bodies may be set on fire at a considerable distance; they must be directed, however, upon a body that will absorb or retain them, if they are directed upon a piece of glass, it will not be heated, nor will any transparent body, such as air, or water. In these cases, the heating power of the sun's rays, is not augmented by concentrating them; the effect is owing entirely to the great number of rays which are brought upon one point.

Combustion.—Among all the natural phenomena which daily take place around us, there is none more wonderful than combustion, and there is none less understood; and yet its vast utility seems to demand that all should know its cause, and the relative powers of the various combustible bodies which are used in the arts and trades, as well as for domestic purposes.

If a piece of iron, and one of wood, of the same size be exposed to the same heat until the iron is red hot, quite different effects will be produced upon them. The iron continues to acquire heat, up to a certain point, where it will remain, while the wood will heat to a certain point, and then suddenly become much hotter of itself; affording at the same time abundance of heat and light. After a short time this heat and light will diminish, and finally cease, although still exposed to the same heat as at the beginning. If the two bodies be now withdrawn from the heat and permitted to cool, the iron will be found to have undergone no change, while what was wood is quite another thing, having lost its shape, weight and color, and is no longer capable of being set on fire as before. Again, if charcoal be heated to about 800° , it takes fire and becomes intensely hot, which after a time diminishes, and finally ceases, when it will be found

that it has entirely disappeared, except a very small quantity of ashes. What has become of it? It has been almost entirely converted into a peculiar kind of air or gas, called carbonic acid gas, (*dead air*), which has escaped, unless the experiment was conducted in proper vessels for collecting it. If collected, it will be found to greatly exceed in weight the charcoal first heated.

In order that a body may burn, oxygen gas is necessary. And as the air we breathe is a mixture of this gas and another called azote, or nitrogen, common air is said to be necessary in order to enable a body to burn, or in other words to undergo combustion. In every case of combustion, heat and light are produced, and there is a total change in the nature of the body burnt. The immortal Lavoiser was the first who explained the phenomenon of burning in a satisfactory manner. He supposed that oxygen is combined with heat and light; and when therefore a body is burnt, the oxygen gas of the air is decomposed, heat and light are set free, while the remainder of the gas, or its base, combines with the body burnt, and forms the product, ashes, carbonic acid gas, &c. The products will not burn, of course, because they are already combined with as much oxygen as possible.

We may now explain the cause why the products of the charcoal mentioned above, weigh more than the coal first used. The oxygen has weight, and having combined with a part of the coal, forming the dead air; of course, the products weigh more than the coal alone.

The quantity of heat evolved during combustion is not only highly important as an object of economy, but interesting in a philosophical point of view. Several philosophers have investigated the subject, and no one with more success than our countryman, Count Rumford. He found how many pounds of ice were melted by the burning of one pound of the body tried. The following table shows some of his results.

	lbs.		lbs.
Olive Oil	93,07	Tallow	111,58
Rape-seed Oil	124,09	Alcohol	67,47
Wax (Bees')	126,24		

The following table exhibits the results of a set of simi-

lar experiments conducted in the same manner as the above, on some of the common combustibles which are used in New England, as determined by the writer of this tract.

			lbs.	oz.
Oak (white), (<i>Quercus alba</i>)	dry	- -	39	4
do.	do. green	- -	32	1
Oak (yellow) (<i>Quercus castanea</i>)	dry	- -	41	7
do.	do. green	- -	35	5
Hickory (<i>Carya squamosa</i>)	dry	- -	43	3
do.	do. green	- -	40	
Maple (rock) (<i>Acer saccharinum</i>)	dry	- -	43	1
do.	do. green	- -	41	10
Maple (white) (<i>Acer dasycarpum</i>)	dry	- -	39	
Pine (white) (<i>Pinus strobus</i>)	dry	- -	29	12
do.	do. green	- -	22	
Pine (pitch) (<i>Pinus rigida</i>)	dry	- -	33	9
do.	do. green	- -	29	2
Liverpool Coal	- - -	- -	80	
Lehigh Coal	- - -	- -	89	4
Rhode Island	- - -	- -	89	12
Charcoal (oak)	- - -	- -	97	1
do. (pine)	- - -	- -	70	

The heating power of all the above woods is found to be considerably augmented by drying them in a hot oven. The wood, when burnt, was in the state of small shavings.

Heat is likewise produced by percussion, friction, and the mixture of certain substances; also by electricity, &c, all of which with propriety we shall defer to another opportunity, and conclude this essay with the advice of a great and good man. 'If you would discover the hidden causes of nature's grand operations, you must first learn and elucidate those which are simple and of every day occurrence before your eyes. It is from small causes that great effects are produced.'

AGENTS

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SCIENTIFIC TRACTS.

NUMBER VII.

ENTOMOLOGY.

AMONG the different sciences which of late years have been zealously studied in this portion of our country, none, perhaps, have received more attention than several branches of Natural History.

A taste for these pursuits is rapidly increasing, as the pleasure and instruction received from them are pointed out by those who have diligently and faithfully investigated them. But while peculiar circumstances have rendered some of these branches more popular than others, a few have been neglected almost altogether. Thus while the objects of some may have been eagerly sought after at much labor and pecuniary expense, and those of others have been carefully examined and accurately arranged, several have been permitted to remain unheeded and unsought for.

Mineralogy, indebted for much of its popularity as a science among us within a few years, to the brilliancy of a star in the East, has become not only a delightful pursuit for the student at our Universities, but an amusement for the man of leisure, and a fashionable recreation among the most wealthy.

The variety and beauty of our plants — the pleasing associations at all times recalled by reverting to the days of our childhood, when we so joyously plucked them — and the unusual facilities offered for their study, have rendered them the objects of general admiration. Few are there among us who have not some slight acquaintance with this fascinating branch; who cannot describe the parts which compose a flower, and distinguish many of our frequently observed species. Here we have great inducements to proceed, being furnished with many invaluable aids. Dictionaries and manuals, written in the

most simple and attractive manner, — freed from all the useless terms with which the older writers had embarrassed the subject, and pointing out its pleasures and advantages, have been afforded us by those who were well qualified for the arduous duty. An impetus was long since given; and the establishment of Professorships at our colleges, and the introduction of elementary works on this subject, not only into seminaries devoted to the education of our young ladies, but also into the schools of children, prove how desirable the possession of this branch of knowledge is considered. This taste, enthusiastic, as it may almost be called, is yearly increasing by means of the spirited efforts of our horticulturists, who, not content to cultivate the natives of our own soil alone, are continually introducing many varieties of rare and choice exotics.

Zoology has not been extensively studied with us. Comparatively few, very few, have devoted themselves to an examination of the animal world, although in each of its departments, individuals have distinguished themselves by their industry and talents; and invaluable papers relating to objects in most of these departments are treasured up in our scientific periodicals.

Our birds have been minutely and correctly described, and splendidly figured by Wilson, and Bonaparte, and Audubon; and we are soon to be gratified with a work on these animals from the pen of Nuttall, whose name is a sure pledge of the accuracy and perfection of the great undertaking.

Conchology, the study of shells, has been more attended to, than either of the other branches of this great division. The objects of this class are generally treasured up for their beauty; and on this account it is a favorite branch with our young ladies. Cabinets formed by them are often met with, showing a taste, and perseverance, and knowledge, of which they may well be proud.

But while these branches are pursued with such unabating zeal, the same individual oftentimes takes but a cursory view of the most delightful branch of the works of nature — the Insect creation. To procure the humblest

moss, he will toil up the rugged mountain with eagerness, regardless alike of fatigue and exposure, and feel richly repaid by the possession of his undescribed treasure. For a beautiful shell, with cheerfulness will he part with his last dollar, and proudly add it to his finely polished and carefully arranged cabinet. But why, it may be asked, is the study of insects less cultivated than either of the other branches? Why have they each enthusiastic disciples wherever we may look, while those who devote themselves to this branch, are comparatively so few? Would the lover of nature, he who delights to retire from the scenes of a busy world, and amid the harmony about him, forget the bitterness of his daily cup, cherish a fond delight for the vegetable kingdom, or listen enraptured to the free and delicious notes of the joyous songsters, and not even capture the splendid object before him, or bestow upon it a passing moment, if from it he could reap either pleasure or advantage? I would endeavor to answer such questions, — to remove the objections which may exist to the study of entomology, and offer such motives as may appear why it should be cultivated with equal devotion as the other departments of Natural History.

OBJECTIONS.

Many an individual has in childhood imbibed an aversion for insects, from the circumstance of having met with them in his articles of food; or having observed them in situations, little to be desired either for their cleanliness or comfort; an aversion, which, like other early impressions, is extremely difficult to be removed; increasing, unless an effort be made to destroy it, in proportion to the frequency of the exposure. Who does not, if in his boyish days he has often noticed an insect hovering over a stagnant pool, or glutting itself with putrefying matter, particularly if he has seized that insect and found it not only overrun with parasites, but emitting a most offensive odour, even more unpleasant than that arising from its repast — who does not remember, that the mere presence of that insect, preserved perhaps by some zealous companion, did for a time recall the prejudices which were so early formed, and all the trifling

circumstances which existed to fix them? This disgust, occasioned by an individual, involuntarily leads many to avoid the whole class.

The *inconveniences* suffered from insects, and the injuries produced by them, cause many superficial observers to turn from these to other objects, more worthy their interest. The musquitto, and flea, and bug, leave impressions not easily to be effaced. The acute sufferings of a night are not forgotten for years. But when, in addition to these annoyances, our clothes, and furniture, and books, — the dearly collected specimens of the naturalist, and the cheaply purchased works of art are all ruined by various species of this class, no slight degree of philosophy is required, to revert to these animals without awakening unpleasant associations. And if beside these, we perceive the merciless destroyers blasting our forest and fruit trees, our most valuable vegetables and choicest plants, — depriving us of our grain when it is carefully gathered into store-houses, and thus adding to the distresses of the poor, when they are least able to bear them, it is not surprising that a feeling of uneasiness should often be awakened; nor that the mind which dwells upon the clouds only in the horizon, should forget that they are sometimes dispelled. The entomologist, even, cannot read the histories of some particular species, without agitation. The locust, for example, must ever excite a degree of terror in the minds of the most enthusiastic. Although Arabia appears to be the favorite resort of these dreaded intruders they have visited the other countries of Asia; and not only these, but Africa and Europe also have felt their unrelenting havoc. From the earliest times we have been taught to shudder at their devastations. And removed as far as we may be from the countries of this genus, we cannot carefully read of the ruin produced by them, without a sensation of horror. Not only do they destroy every part of plants, and trees, and grasses, the root, trunk, leaf, bud, fruit, with merciless voracity, but every green thing is swept off without distinction; thus depopulating nations, and carrying more dread with them than the most powerful armies. Nothing but desolation can be connected with a host of these, extending five hundred miles, and so dense that when on wing, like

an eclipse, they completely hide the sun. But this is not all. These immense multitudes, when they have destroyed everything about them, die; and their decomposing carcases often produce the plague. *One hundred thousand men* have been swept off in Africa in one season, and nearly a million of men and beasts in Italy, by this cause.

The *insignificance* of the animals belonging to this class, prevents many from engaging in the study. A senseless worm, say some, is unworthy the attention of man. Other objects should occupy his thoughts. Nobler pursuits should claim his precious time.

Others, alive to *sensibility*, at once shrink from a pursuit which to them appears cruel in the extreme, and thus suppress an inclination which might prompt them to become benefactors to their fellow-men.

MOTIVES TO THE STUDY OF THE SCIENCE.

Ought we not to remember with gratitude, such animals as are hourly removing from around us, the causes of uneasiness or the elements of disease? Should we avoid the medicinal plant, satisfied as we may be of its value, on account of its fetid, nauseating smell, one of its principal characteristics, which renders it discoverable by all? Should we not rather regard it the more for disclosing its nature to us, at our first meeting, while as yet we are strangers?

I have said that the inconveniences suffered from these animals deter many from examining them. What stronger argument, I would ask, can possibly be offered, why our attention should be directed to any subject than this — that by our ignorance of it, we are made to suffer; and that in proportion to our knowledge, are not only our inconveniences lessened, but our pleasures increased? This very circumstance, which is urged as an objection, prompts many a cultivator of the soil to become an entomologist; and thus he is enabled, not only to prevent the injuries which would have occurred to his own harvest, but also to render an essential service to thousands, who had previously suffered with him. If our persons are the objects of attack, additional motives exist. Not only will our ill-founded fears, as to the increase and ravages of any

particular species be removed, but we shall be able to lessen the degree of temporary inconvenience suffered from them, and also to ward off several loathsome diseases.

The *minuteness*, and apparently *imperfect formation* of these animals, undoubtedly deter many from becoming interested in their history. With no elevated mind could these circumstances be regarded as objections to their examination. They would rather present themselves, as strong reasons why this science should be pursued — as the defects here would be the mere absence of organs or powers possessed by others, destined for different purposes, and would most forcibly prove the existence of a plan in which can be traced consummate skill, creating at one moment the most complicated of living beings, — then leaving us to admire and wonder at the construction of objects, the simplicity of whose formation renders them more accessible to the comprehension of man. But if the absence of something which is essential for the performance of necessary operations be alone a defect, then no imperfection can be pointed at, as a characteristic of the animals whose history it is delightful to study. Furnished with faculties for the execution of all the purposes of their existence, no one can direct his attention to them unprejudiced, without finding himself involuntarily interested in their study: and when he discovers them possessed of all the senses he is blessed with, and observes, besides their perfect beauty and curious external formation, a something which he at times almost believes cannot be mere instinct — when he reflects upon operations, the magnitude of whose design can scarcely be realized, and whose completion can hardly be credited, he is compelled to exclaim like a distinguished Roman philosopher, when examining these same objects, ‘the nature of things is never more complete than in the least things.’

From an erroneous idea that much *cruelty* must necessarily be exercised in the pursuit of this science, many are deterred from attending to it. If the individuals belonging to this class were as susceptible of suffering as those of some other classes, — and were it absolutely ne-

cessary that *many* individuals of the same family should be destroyed in order to become acquainted with their histories, then might this be offered as an objection. But although all the senses are possessed, they do not exist with the same power as in other classes. It is not an uncommon circumstance for an insect to leave a leg in the hands of the entomologist, and not only fly off apparently as joyous as ever, but in a moment to alight and partake of its accustomed food. Kirby remarks, 'I have seen the common cockchaffer walk about with apparent indifference after some bird had nearly emptied its body of its viscera. An humble-bee will eat honey with greediness, though deprived of its abdomen. And I myself lately saw an ant, which had been brought out of the nest by its comrades, walk when deprived of its head. The head of a wasp will attempt to bite after it is separated from the rest of the body; and the abdomen under similar circumstances, if the finger be moved to it, will attempt to sting.' M. Riboud speaks of a beetle which survived fourteen days with a pin passed through it, as thick as its thigh. Dalzell relates that a butterfly lived a month after being stuck through with a pin, and after he thought it had been destroyed by sulphur. And our own Say tells us, that he observed a butterfly feeding with eagerness after it had escaped from him, impaled with a pin. Leuwenhoek had a mite which lived eleven weeks, stuck on the point of a needle, under his microscope. Vaillant, the African traveller, endeavoring to preserve a locust, took out the intestines, and filled the abdomen with cotton, and then fixed it down by a pin through the thorax: yet after five months the animal still moved its feet and antennæ. But if these remarks do not prove this objection to be ill-founded, I will change the argument. If suffering should be borne, — if a confined insect should be made to endure agonizing struggles, — if by its captivity any useful purpose can be gained, the entomologist cannot be called cruel. Cruelty implies the 'unnecessary infliction of suffering,' to gratify depraved feelings; the disposition to inflict pain, when no possible benefit can be derived from such an act. But it is not shown by pursuing any department of natural history, when the feel-

ings which prompt us to study them are the most generous and elevated of our natures.

Having dwelt upon such objections as would most probably be offered to the cultivation of this science, by those who oppose it, and having endeavored to show their futility, a few inducements shall be offered to its study.

We are so prone to avoid whatever at first sight is displeasing, so willing to lend a ready ear to whatever lessens the value of any object, so liable to be more impressed by the remembrance of an injury than the possession of a blessing, that most of mankind pass by this noble, elevating study, as if it were useless; and forgetting the utility of many of this class of creation, see in it nothing which should employ the rational mind. These incorrect views are removed solely by observation and reflection. No one department of the works of nature exhibits more powerful motives for its successful cultivation than this, if the number, variety, beauty, or perfection of its subjects be considered. At all seasons, and in almost every situation, individuals may be observed belonging to this class. The lovers of other branches may make but comparatively few additions to the objects they already possess. But the entomologist, even if he should be confined to the close and less pure air of a city, and allowed to travel over paved streets only, and this too, while in the performance of his necessary duties, has frequent opportunities of noticing species with which previously he had been unacquainted. And to the naturalist, what can be more grateful, than to find, wherever he may go, some new object to admire, some fresh incentive to the pursuit of his favorite study. To the lover of nature, the argument just offered will appear weighty. But I am well aware many will require stronger reasons, than that facilities exist for the cultivation of a science, and that much gratification of feeling is to be derived from attending to it, ere they think it worthy their consideration.

For such, other reasons can be offered, strong enough to convince any one of its advantages. As the agriculturist, by a minute acquaintance with the habits of this order of beings, is enabled to prevent in a great degree the injuries he would otherwise inevitably be compelled

to suffer, so is he restrained from much useless labor, and no little voluntary suffering. He neither amuses us by burying in the earth, with the intention of destroying them, immense quantities of caterpillars which spend a part of their lives there; nor by cutting down valuable trees, to spare others, because the insects which inhabit both, appear to him as belonging to the same species. He is enabled also to discover that some of our most common insects are of much value to him, in checking the increase of others, which would be injurious to his crops. An acquaintance with this subject will also remove many erroneous ideas which had been formed respecting the characters of these individuals, and the purposes for which they were created. The ticking of the *death-watch* will no longer be listened to with silent shuddering; nor will the protuberance on the oak leaf be examined with fearful forebodings, but the fœtal larva will be allowed quietly to go on to perfection, whether it foretels war, pestilence, or famine; and the minutest and most neglected insect, when the purposes of its existence are well known, will prove how injurious oftentimes are preconceived opinions.

IMMEDIATE ADVANTAGES DERIVED FROM INSECTS.

Another reason should be dwelt upon. The direct benefits derived from the individuals belonging to this class, should claim for them a greater share of attention. Well do I know, that all other arguments which can be offered, are slight in comparison with this. We are ever ready to engage in a pursuit, when it affords a prospect of remuneration, which before hardly claimed a thought; and often become from this cause zealous enthusiasts, where previously we had studiously avoided engaging our feelings. And here, I would refer particularly to the immense profits which may be received from insects, as articles of commerce. None, save those who have particularly attended to this subject, can for a moment conceive the extent of this traffic. Not only are various species used in the arts, but in some countries as articles of food, many have an extensive circulation. A few examples only shall be offered at the present time. To entomology must we look for several of our most beautiful and valuable dyes. A

perfect scarlet is obtained from the same insect whose secretion, under the name of Lac, is applied to so many useful purposes ; and with the crimson dye of the Cochineal insect, all are familiar. This insect, the *Coccus Cacti*, is a native of South America, and is particularly cultivated in Mexico. When the female, which is alone valuable, has arrived at its perfect state, it fixes itself to the surface of the leaf, and encloses itself in a white cottony matter which it secretes. When it has deposited all its eggs, it shrivels and dies ; but as its colouring qualities are thus destroyed, those who raise them are careful to kill them before this time, which they do by brushing them off the plants, and applying the fumes of hot vinegar, or throwing them into boiling water ; they are then dried and imported into Europe. The cultivation of the cochineal insect requires much attention, and the gathering of them also. But the time of those thus occupied is well employed, this insect furnishing the most valuable dye obtained from this class of animals. Humboldt tells us, that the quantity annually exported from South America, is there worth upwards of five hundred thousand pounds sterling ; and it has been said that the Spanish government is yearly more enriched by this article, than by the produce of all its gold mines. The directors of the East India Company offered a reward of six thousand pounds to any one who should introduce it into India. In commerce, this article is almost always adulterated, different substances being mixed with it, and colored by it ; and Dr Paris, in his *Pharmacologia*, remarks, that a very considerable number of women and children get a support in London, by forming in moulds made for that purpose, particles of dough, and coloring them with cochineal.

The Lac insect referred to above, another species of *Coccus*, lives upon a species of *Rhamnus*. It is nourished by the tree, and there deposits its eggs, which it defends by this secretion, which also serves as a habitation for the perfect insect, and answers for food to the larva. This lac is formed into cells, finished with much regularity and art. The flies are invited to deposit their eggs on the branches of the tree, by besmearing them with some of the fresh lac steeped in water, which attracts

them, and thus gives a larger crop. When purified — which is done by first removing the twigs, leaves, and all the foreign substances, then breaking it into small pieces, placing them in a canvas bag, which is applied to the fire until the liquid lac passes through its pores, when it is taken off the fire and pressed — it is used for making sealing-wax, beads, rings, and various ornaments.

The Bee also furnishes an article of much importance; honey, the juice of plants, changed in its properties while in the stomach of the bee, is no small source of revenue to many individuals. Although most of the honey consumed is obtained from the hive-bee, great quantities are in various countries collected from different species of wild bees. Thus, in South America, much is obtained from nests in the trunks of trees. The beautiful rock-honey is also the produce of wild bees, which form their nests to rocks. Large quantities of hives of a bee differing from our common bee, are carried to different situations on the Nile, as the food of the bees at different places, fails them. The French have learned a lesson from this, and been profited. As the flowers decrease at any particular spot, compelling the bees to go far from their hives, the proprietors of the hives place them on a barge well covered, and they pass down the rivers, collecting the honey on the banks. In Spain the number of bee-hives is very great: Mills relates that a single priest was known to possess five thousand hives.

Wax, a substance which is secreted from honey, and transpires through the pores of the skin of the bee, and the article of which the bee forms its comb, is to some countries a source of great revenue. Thus we are told, that upwards of eightythree thousand pounds' value are annually sent from Cuba to New Spain; and that the whole quantity exported from the same island, has been worth upwards of one hundred and thirty thousand pounds in a year. By those who are never satisfied of the expediency of any object, who would prefer to receive everything of others, rather than make the slightest effort themselves, objections have been advanced as to the probability of our succeeding in rearing bees in New England. Our mild weather continues so short a time, say they, that the

bees have time enough only to provide a sufficiency for their own wants during the remainder of the year. We ought not to be surprised at the misrepresentations of foreigners respecting our climate, while we have so many traducers at home; nor feel irritated at the insinuations which would imply the degeneracy of all created things in a traveller, while those who should repel are so ready to give such errors circulation. That much may be done has already been proved in many of our States. And if at any particular spots it is desirable to establish hives, previous to the growth of such seed as may be sown, they might be moved as in Egypt and France, to points where food may be found in great abundance, and afterwards restored to the appointed place. But even if this should be impracticable, and if the quantity of honey produced by the bees were but little besides what would be necessary for them, if they should be allowed to feed continually and to the extent of their appetites, much might be gained by placing the hives, after all the honey was collected, in situations where the temperature should be so low as to render the bees inactive, and consequently requiring but little to nourish them, until the returning spring.

* The product of another insect, the caterpillar of a *moth*, whether it be looked upon as an article of commerce, or an object of domestic employment, is well worthy the attention of our country. The raising of silk-worms engaged the attention of an emperor of China, so long ago as twentyseven hundred years before the Christian era; and an empress first attended to the manufacture of silk. This occupation for a long time was confined to ladies of the most elevated standing; but gradually became an employment for females generally. After the quantity of silk manufactured was sufficient to clothe all classes in China, it was used as an article of exportation, and was carried from the northern parts of the Chinese dominions to every part of Asia. In 555, two monks brought from China in their hollow staves,

* The following remarks upon the silk worm have been previously inserted in a number of the *Ladies' Magazine*.

silk-worms' eggs to Constantinople; and thus Europe first became possessed of the power of raising silk. In Greece, as in China, females of the first families commenced the care of silk-worms. Next to Greece, Italy attended to the rearing of these insects. About the year 1600, Henry IV. introduced the raising of silk-worms into France, which now derives from their labors 23,560,000 francs annually. Although in 1180, silk was imported into England from China, which was earlier than it had been received in France, still nothing of importance was done towards the introduction of the caterpillar into England, until within the last eleven years, -- two hundred years after France had set the example. Although two preceding attempts had failed to render the cultivation of silk important in Germany, during the past twelve years great efforts have been made there, originating with the Agricultural Society of Bavaria. Prussia and Sweden also, have not been idle; and in the former of these, it has been proved, that 'silk equal to that of Italy may be produced, affording greater profit than any other branch of rural industry;' while that raised in the latter country would show 'that the silk raised near the polar circle, is equal in strength and firmness to any species cultivated in more temperate climates.'

The cultivation of the silk-worm in this country, is becoming an object of so much importance, that during the year 1828, the Senate of the United States, ordered 2000 copies of a letter from the Secretary of the Treasury, transmitting all the information which could be collected respecting the cultivation of silk in the Union, to be printed for the use of its members. In Virginia, Georgia and South Carolina, the silk-worm has been reared for many years. In 1760, silk was first raised in Connecticut. Since then in New Hampshire, Vermont, Massachusetts and very lately in Maine, this subject has attracted the attention of economists. Connecticut has been eminently successful in her efforts:—in 1825, in the town of Mansfield alone, in that State, the silk manufactured was three hundred pounds—valued at *fifteen thousand dollars*:—in 1826, the County of Windham manufactured silk to the amount of fiftyfour thousand

dollars. It is estimated that five thousand dollars' worth of silk is annually sold in one County, (Orange County) in New York; and the whole sale of this article in that State, is calculated at fifteen thousand dollars. When it is considered that the greater part of the labor may be accomplished by females and children, and that it is not only a healthful exercise, but an agreeable amusement, it will be thought not a little surprising, that we are so willing and ready to import silk from abroad.

A GENERAL VIEW OF THE INJURIES AND BENEFITS PRODUCED BY EACH ORDER OF INSECTS.

But perhaps *many* might be persuaded to engage in the study of entomology, if the benefits derived from, and the injuries produced by each order of insects, were exhibited in a general manner, that they might be readily compared.

The first order is called Coleoptera, from the Greek words *koleos*, a sheath — and *pteron*, a wing — referring to the strong elytra or external wings, which protect the true wings. Among the genera of this order which are most common, are the beetle, stag-beetle, carrion-bug, weevil, lady-bird, blistering-fly, water-beetle, &c, &c. From the ravages of the first order of insects, man suffers extremely:—although our *persons* are incommoded as little perhaps by the animals belonging to this order, as either of the other orders, still the objects by which we are surrounded, those necessary to our *subsistence*, as well as articles of luxury and ease, are all subject to their depredations.

But if the many are not useful, the few are of infinite value. Decomposing substances, while they are removed from our view, are carried by these animals into the earth, and thereby tend to enrich vegetation. Noxious genera are held in detestation by others, which offer us no molestation, while some species afford subsistence to others. Thus the Aphides, the small flies, or (as they are generally called) lice, so common upon many of our plants, are in some seasons devoured in immense quantities by our beautiful lady-birds; and the females of the cockchafer, one of the most injurious of the tribe to the

agriculturist, are destroyed at the moment they are most to be dreaded, by the genus of Ground-beetles. Nor do these afford sustenance to animals of the same scientific class alone. Our native birds, those which follow on wherever cultivation is, — whose delightful notes meet the ear at the rising of the sun, — whose melody cheers the husbandman fatigued at noonday, — and by whose evening concerts the pure heart is elevated and enraptured, — which teach us a glorious lesson of confidence, by rearing and educating their young at our very doors — these also are provided for by the existence of noxious insects: — and little does he study his own interest, whose selfishness causes their destruction. Other animals also feed upon insects. I am not compelled to go back to the Romans, to speak of their larvæ fattened to glut the appetites of epicures; nor to point to the African greedily devouring his roasted caterpillar, while the larvæ of one of the largest species of beetle, is at the present day an article of luxury with many in South America, and is served up at the tables of some of the most wealthy inhabitants of the West India islands. But from no insect belonging to this order, I might almost have said this class, do we derive so much benefit as from the genus *Melœ*, in which is found the blistering-fly. The blistering, or as it is called in commerce, the Spanish-fly, is found in large quantities in the South of Europe; and is particularly abundant in Spain. They are collected from the leaves of different trees in summer, and are afterwards destroyed by the fumes of vinegar, and dried in the sun; when applied externally to the human body, they act as a powerful vesicatory; when given internally, as a stimulant of great efficacy. In many derangements of the system, they are, in the hands of the judicious practitioner, the means of preserving many of our race. When exhibited by the ignorant empiric, they are not unfrequently productive of the most severe sufferings and lamentable deaths. Our common *potato-fly* is one of this genus of insects, and while it possesses all the virtues of the Spanish-fly, it does not produce the bad symptoms, which often attend the employment of that remedy: and Professor Barton of Philadelphia, after

employing both for a long time in his practice, gave the preference to our native fly. It however cannot be collected here in sufficient quantities to supply the demand, and consequently is not so much used as the foreign insect. The active virtues of the Blistering-fly, depend upon the existence of a *principle*, which has obtained the name of *Cantharidin*.

The second order, is named *Hemiptera*, from *emis*, the half, and *pteron*, a wing. The outer wings of this order, are semicoriaceous: they are not so strong as those of the first order, but more so than the remaining orders. This includes the cockroach, locust, lantern-fly, water-scorpion, bug-plant, louse, &c. &c. The 1st genus, as arranged by Linnæus, is the cockroach: this is an extremely troublesome animal, not only destroying our articles of food, but in many cases, our garments and books. By the ravages of the Aphis, or plant-louse, whole crops are often destroyed; our esculents and valuable plants; our fruit trees, as well as those of our woods, are all injured by this insect: by suction, it abstracts from the tender shoot its nutriment, and blasts the leaf by its peculiar secretion. This secretion is sometimes enormous; and not only by its quantity completely encases the plant, but by its saccharine nature, affords a resting place for noxious insects. The cocci also, which look like protuberances upon the stalks of plants, do considerable injury by drawing off the sap, and thus destroying life. To refer to any more genera of this order, would be needless. It is time to turn to those of this order which are of value to us. In speaking of the advantages derived from many insects of the preceding order, I referred to some which kept other species in check, by subsisting upon them. In this order we find the Mantis tribe; those whose peculiar appearance has given the idea of sanctity, one of the most ferocious tribes of insects, even carrying there animosities so far as to destroy each other. But to the coccus are we to look, as the most valuable genus of this order. By a species of this genus, is produced the Pe-la, or white wax of China. The Chinese cherish these insects by stocking some species of trees with them. This secretion begins

to appear about the commencement of summer, and is collected in the autumn. This wax is used by the nobility, and also by public speakers, to excite them. To the Lac, and also to the Cochineal Coccus, I have referred above. Besides the dying property of the Cochineal Coccus, while many unhesitatingly deny it any medicinal virtues, it is still employed by numerous physicians of experience and eminence, as a stimulant medicine.

Like the larvæ of the preceding order, some of the individuals belonging to this, are used as articles of food. That genus which has often produced such extensive suffering, the locust, has in many countries had its devourers. At Mecca, in times of famine, they have been ground up and mixed with flour for cakes: in Greece, and the Barbary powers, they have been an article of merchandize; and the Hottentots, although their vegetation may be ruined, joyously fatten themselves upon cooked locusts.

The third order is composed of such insects as have their wings covered with scales. This is called *Lepidoptera*, from *lepis*, a scale. Three genera only are included in this order. The butterfly, hawkmoth and moth. The individuals of this order are the most beautiful of the class, and often claim the admiration of those who would absurdly cherish for others an inexplicable disgust. Few as are the genera belonging to this order, their ravages are far from being slight;—their advantages are far from unimportant—although the caterpillars of the 1st genus, *Papilio*, the butterfly, are sometimes slightly pernicious, to the other genera, the moth and hawkmoth, we are to look principally for the causes of our injuries. A species of moth does incredible mischief in some seasons to grass. We are told that about half a century since, the fields of Sweden were rendered quite dry by these, as if a fire had passed over them. A small species of moth destroys our grain; our vegetables also suffer from their inroads; while others destroy the bark, and leaves, and blossoms of our fruit trees. Many forests also, in our country, have thus been seriously injured. The foliage being removed when the heat was very great, the unsheltered trunks have

yielded up their lives. The vine, too, is often entirely destroyed by a caterpillar of this genus, on the borders of the Black Sea: as soon as the buds open, they eat them off, especially the fruit buds, and devour the germ of the grape: two or three of these caterpillars will so injure a vine, by passing from one germ to another, that it will bear no fruit the next year. But their depredations are not confined to the vegetable kingdom. The larvæ of several species of moths do much injury to the hive bee; inclosing themselves in tubes of wax, they dwell there, unmindful of the bees. Our farmers have been almost discouraged some seasons, by the depredations of a moth, which utterly ruins their hives, and which has obtained the name generally, of the bee-moth. As however, it is ascertained that the perfect insect deposits its eggs only in clear dry spots, it is thought the evil may, in a great measure, be removed, by placing the hives upon the ground, or strewing earth to the depth of several inches upon their floors. Experiments lead us to hope much will be gained by this method of hiving. Nor are insects the only animals affected—man himself is not wholly exempt from their attacks. We are told by Azara, that in South America, there is a large brown moth, which deposits its eggs in a kind of saliva, upon the flesh of persons sleeping naked; introducing themselves under the skin without being perceived, they occasion swelling, accompanied by much pain and inflammation. Although the caterpillars of this order are, among the Chinese, and the inhabitants of New Holland, an article of *food*, and are considered by the Moors one of their greatest delicacies, our chief advantage is derived from individuals of the third genus, *Phalena*—the moth—and from that species particularly, which subsists upon the white mulberry tree, and supplies us with silk.

Insects having four membranaceous, naked wings, reticulated with veins, or in which the membranes look like net work, make up the fourth order, which is called *Neuroptera*, from *neuron*—a nerve. The dragon-fly, may-fly, and spring-fly, are among the genera of this order. Although the benefits received from this order are of less magnitude than those derived from several others, the

injuries suffered from its subjects are unimportant, and I might say, unknown. The voracious and tyrannical *dragon-fly*, may perhaps destroy in its fury many species of insects, which are of value to the husbandman; but as its instinct prompts it to feed upon many noxious species, it ought perhaps to be regarded as a blessing, rather than a curse. The next genus, *Ephemera*, the *spring-fly*, although its existence is continued but a day, affords a valuable substitute to many farmers in Europe for manure. Scopoli, the historian of the insects of Carniola, remarks that the peasants in his neighborhood are dissatisfied, unless they can individually, collect at the times of their appearance, at least twenty cart loads, to strew over their grounds. The *Hemerobius*, or *golden-eye*, in its larvæ state, is of great value also, in the destruction of the *Aphides*, or *plant-lice*.

The fifth order has four membranaceous, naked wings, and is called *Hymenoptera*, from *umen*, a membrane. This order has been ranked at the head of the class by some naturalists, on account of their admirable economy. The *gall-fly*, *saw-fly*, *ichneumon-fly*, *wasp*, *bee* and *ant*, are arranged by Linnæus, in this order of insects. Some genera are extremely injurious, while others are of immense value.

The *Cynips*, or *gall-fly*, when its larvæ are deposited in unusual numbers upon a leaf, must detract largely from its nourishment: consequently, whole trees may, in some seasons, suffer from their presence. The second genus, *Tenthredo*, commonly called *saw-fly*, is the most dreaded insect of this order—its vulgar name is derived from the instrument by which it makes an incision in a leaf; this instrument, is a *double saw*, which in using, the insect first throws out one, then the other alternately, until a sufficient incision is made; when they are both retracted, and the egg is deposited from between them. Although the larvæ of this genus generally feed on the rose, and the willow tree, our grain, vegetables and fruit trees, have been at times, seriously injured. One species of these larvæ, which has received the name of *slug-worm*, and which has been admirably described, its changes and its injuries, by the late Professor Peck, in a volume of the

papers of the Massachusetts Agricultural Society, caused serious alarm in this country, about thirty years since. At that time, some of our most valuable trees were completely stripped of their leaves, and the crops of the succeeding years blasted by their ravages. I will not speak of the stings of the bee, nor the wasp, nor the Ichneumon-fly, for although I, with others, may have suffered from their venom, the suffering was deserved, and I am inclined to believe, that in almost every case, in which injuries are produced by these insects, they act on the defensive.

This order of insects is extremely important. If the injuries produced by them have been minutely detailed, obligations for benefits received shall be as readily acknowledged. And here, as strongly, perhaps, as in any order of nature, do we observe the necessity of understanding perfectly the character of an individual before we decide upon merits — of reflecting upon the ends of actions, before we think of them as worse than useless. Thus the protuberances upon our leaves, produced by the gall-fly, while they disfigure them, and in some instances greatly injure the tree, thus causing vexation to the possessors, not only are eaten as delicacies by the inhabitants of the Levant, and form a considerable article of commerce at Constantinople, where, preserved, they are exposed for sale, but they also furnish us with a valuable dyeing material; and what is of still greater importance, we are indebted to them for the means of forming ink.

The ant, too—little do we think, when incommoded by this genus, that any of its species are important to man: but we find, upon reflection, that the anatomist entrusts his nicest dissections to the inmates of an ant-hill, with perfect confidence in their skill. The cockroach in Ceylon, is destroyed by a species of ant — and in the eighth volume of the Quarterly Journal of Science, Literature and the Arts, is a very interesting paper by a Capt. Bagnald, who says, while in the West-Indies, he had repeated opportunities of watching the movements of these insects; he saw them often destroy spiders and cockroaches, and upon one occasion, he observed them

encounter a centipede, which, however, they did not put to death, until they had completely encrusted him; and though in the conflict, thousands of them were destroyed, they finally killed him. Nor are these all the advantages derived from them: a low priced brandy is made in Sweden, of rye and ants—these insects supplying a resin, an oil, and an acid. And in that country, they are not unfrequently eaten uncooked, for their acid taste; the devourers first plucking off their heads and wings. The ichneumon-fly is of essential service, in depositing its eggs, in the eggs or as yet imbecile larvæ—or by checking the progress of the powerful and voracious caterpillar. The sphex, or ichneumon-wasp, is a destroyer of the cockroach; wasps destroy for us immense quantities of flies—and in the interior of New England, their paper nests are used in affections of the lungs.—What their virtues are, the writer knows not: the substance by which they unite the particles of their nests together may perhaps be of a stimulating quality, and thus be enabled to relieve the existing stricture. But the Bee, which has been already dwelt upon, is the most valuable insect of this order.

If in speaking of the order Neuroptera, it was remarked that the injuries they produced were of but small consideration, I must here notice an order, in which but little obvious advantage is perceived, to compensate for its powers of annoyance.

The sixth order of Insects is called *Diptera*—from *dis*, twice, or double; they having but two wings. In this order, we find the various kinds of flies and the musquitto; here we observe not only genera which attack our provisions and ruin them, which harass, and render furious our cattle, and horses, and flocks, but also those which avoid less palatable food, to regale themselves with the blood of man. The first genus, *Cæstrus*, the gad-fly, is the most troublesome, which affects our domestic animals. The gad-fly of the ox, deposits its eggs in the body of that animal, and thus the larvæ are provided for, during the whole winter. You may imagine how troublesome such an insect must be to the animal, particularly if it should suffer from indisposition after the deposition

of the egg. Another species, by irritating the lips of the horse in its endeavors to deposit its eggs there, renders the animal almost ungovernable: while the larvæ of a third species, hatching in the stomach of this animal from eggs introduced by its tongue, produce a disease, oftentimes severe, and which receives its name from the larvæ which produce it. Our inoffensive flocks too, are compelled to suffer from a species of gad-fly, which, depositing its eggs in the nostrils of the animal, feeds in the larvæ state upon the delicate membrane there, causing extreme distress, and not unfrequently, by insinuating itself into the brain, produces death. But these are not the only sufferers: not only does a species of gad-fly deposit its eggs in the abdomen of man, causing great irritation and suffering, in the torrid zone, but in some cases, even destroys life. The larvæ of the second genus, *Tipula*, the crane-fly, in some seasons, do much injury to grass, wheat and corn, by burrowing in their roots. With the inconveniences of the third genus, *Musca*, the fly, all must be conversant: by this genus, our articles of luxury are tarnished, our provisions destroyed, our persons molested, — while some species, not satisfied with one substance, attack all provisions which may be gathered for use by the husbandman: others are abroad, depositing the seeds of ruin in our grain, disappointing the hard working agriculturist. One species, a few years since in this country, from its ravages in our wheat fields, caused no common alarm. Nor is it to be wondered at, that the Hessian-fly should now be thought of with terror, when it is remembered, that it not only attacked this grain as soon as it began to grow, and destroyed every part of it, but also by depositing its eggs in the stem, so weakened it, as to prevent the ear from ripening. Another genus, *Tabanus*, the whame-fly, is at times very troublesome. The horse is a principal sufferer from their attacks—although in Africa, the inhabitants of whole counties are compelled to emigrate yearly to the locations of sand, to prevent their cattle from being destroyed by the attacks of this insect. The *Culex*, or guat, remains to be noticed—the greatest plague of this order. Annoying as the musquitto is to us, when travelling in the vicini-

ity of marshes, or when our rooms are lighted during the evenings of summer—we have but little reason for complaint, when we observe their ravages in other countries. It is said that in South America, soldiers are sometimes forced to sleep with their heads thrust into holes in the earth, made with their bayonets, and to wrap round their necks their hammocks; that a king of Persia, his army having been completely exhausted by these insects, has been compelled to raise the siege of cities: that the Laplander is barely able to exist, with every means of defence he can employ; and that the Russian soldier, although sleeping in a sack, is not always able to live under such excessive irritation. And for all the sufferings experienced from this order, decomposing matter is removed by the infinite tribe of flies, which on every side surrounds us. The larvæ of one species, the inmate of putrid cheese, is a delicious repast for the refined epicure; and it is conjectured that the larvæ of the gad fly, which exhaust the poor horse, are in some cases, a gentle and beneficial stimulant.

The seventh and last order, is called *Aptera*—from *a*, primitive, and *pteron*, wing, and includes all such insects as want wings, in either sex. This order includes the *Lepismæ*, commonly called moths; *Termites*, or white-ants; *Pedicalus*, the louse; *Palex*, the flea; &c, &c. The termites or white-ants, are extremely numerous in warm countries, and very destructive, although wood is their common food; clothes, furniture, books, and almost all manufactured articles, are ruined by them. They curiously avoid injuring the exterior of substances, while they are destroying all within; houses are ruined by them; and when vessels are so unfortunate as to receive any on board of them, much injury is suffered. The genus *Pediculus*, louse, is very extensive. There is scarcely an animal or vegetable, that does not suffer from its own peculiar louse. Our domestic animals, as well as birds, fishes, plants, all have their lice—to man, it is extremely troublesome: but as it has been ascertained that the inconvenience is merely *external irritation*, we ought perhaps to consider it in the light of a proper reward for those who cherish them; as rarely, any one is annoyed,

unless really deserving of their attacks. The *Pulex*, or flea, and *Acarus*, or mite, are also included in this order, and are extremely troublesome.

Although other slight benefits have been derived from several genera, the insects of this order appear to be most extensively employed as articles of *food*.

It would be almost useless to mention any of the distinct and individual cases of this singular propensity; although they might be pointed at, among the most polished nations of Europe; because they would be considered perversions of taste, when the inhabitants of extensive tracts of country offer themselves as examples. The people of New Caledonia eat immense quantities of spiders; and all who have ever read of the Hottentots and Esquimaux Indians, must have been disgusted with their meals of lice.

In the compilation of the above Tract, the system of Linnæus the Swede, has been followed, on account of its conciseness, principally. The entomologist will at once perceive, that it was prepared for the *general reader*, and not for him who would be satisfied only with the more elaborate classifications of the great French naturalists.

SCIENTIFIC TRACTS.

NUMBER VIII.

FOREST TREES.

PART I.

EVERY day brings new and animating proof, that Natural History is rapidly advancing to take the place its importance claims, as a branch of common education. Infant schools owe their uniform and distinguished success, in no small degree, to the use of specimens, pictures, and other illustrations, to exhibit and explain the different departments of nature. The representation and description of animals are equally favorable to the gratification of the feelings of children, and to the development of their intellectual and moral faculties. Geology, when illustrated with specimens, furnishes a most delightful exercise to young minds, and is already introduced into most infant schools, and is rapidly finding its way into elementary schools of every grade.

In behalf of the science last mentioned, it is truly gratifying to learn from various sections of the country, that the second number of this series of Tracts, which treats of Geology, is coming fully up to its design, in acting an humble but efficient part, in bringing its subject in a most attractive form, into schools and families. We are informed from various sources, that it is leading young people, and even children, to convert their walks and rambles into exercises for useful instruction, by examining and collecting specimens of rocks and other minerals, which they find to be scattered around them, with a profusion, variety, richness, and beauty, of which they had never formed a conjecture. While these collections

furnish a most salutary exercise for the physical, intellectual, and moral development of those who make them they add in no small degree to the resources and wealth of our country, by bringing to view its hidden treasures.

When it is known that our earth is adorned and enriched by sixty thousand different species of plants, rendered attractive by an endless variety, the most delicate shades of beauty, and frequently by their lofty and majestic appearance, as well as their various uses, it cannot be denied or doubted that the vegetable kingdom, no less than the animal and mineral, contains a vast store-house of materials, well fitted to enliven the imagination, invigorate the understanding, and warm and purify the hearts of the thousands of the sprightly intelligences constantly blooming into youth, or ripening into manhood. Vegetables, by the variety of their species, the curious workmanship of their structure, the richness of their verdure, the beauty and fragrance of the flowers, and the constant and abundant supply they furnish to the wants of man and beast, present a boundless and exhaustless field for the cultivation, improvement, and elevation of the intellectual and moral kingdom of our Creator, for which his whole material universe was designed. Every plant, from the humblest vine that creeps upon the earth, or the most uncomely moss that hangs upon the wall, to the stately and majestic oak that towers in the forest, fully proves the divinity of the hand which made it, by a striking and wonderful display of wisdom, power, and goodness, which far surpasses everything human.

If such is the character of the vegetable kingdom, the adoption of the science which treats of it, as a branch of common instruction, must be a necessary consequence of enlarged and appropriate views of the subject of education. We hence find that in most schools where instruction is given under the most enlightened and rational views, and upon the largest and most liberal plan, the science of botany forms an essential part of the course. It is already introduced into numerous schools, especially female seminaries, besides the instruction extensively given in the form of lectures, to classes collected particularly for the purpose.

But from some cause, which perhaps it would be difficult to explain, one subject of botany has hitherto been almost wholly neglected, both by teachers and the amateurs of science.

American forest trees, which foreigners inform us, constitute the grandest department of the vegetable kingdom, have been doomed to a strange and unwarranted neglect, unless indeed it is to sweep them by an almost sacrilegious hand, with all their richness and majestic grandeur from the earth, which groans under their weight. The towering oak, which all ages, and even barbarians have acknowledged to be the monarch of their forests, capable of enduring the buffeting tempests of a thousand winters, has been less studied and is less understood by the lovers of science, especially in our own country, than the rarest, humblest, and most useless plant, which some barren knoll supports for a few days or weeks, with a frail and meagre form, but suffers it to wither, die, and disappear by the force of the genial rays of the sun for half a season.

Why our own majestic forests should be thus neglected and abused, while the less stately groves of other nations and other ages have been subjects of general interest, and sometimes of adoration, we shall not undertake to explain. But such is the fact.

It does not speak well for the science, the taste, or the good sense of Americans, that the best, and almost only description of their forest trees which has come to the public, is from the hands of Europeans. Two gentlemen from France, by the name of Michaux, first the father and afterwards the son, crossed the Atlantic for the express purpose of examining our forests, which they ranged from Canada to Mexico. They not only examined our trees with the eyes of botanists, and under the enthusiasm of the lovers of science, but as men of business and common sense, they visited ship-yards, workshops, and other places where they would be likely to learn by observation and from inquiries of those who worked or used the timber they furnish, what are their properties and uses.

The fruits of the science and researches of these two

intelligent and sensible Frenchmen, were several splendid volumes, which by full and practical descriptions of our forest trees, illustrated by splendid engravings, do no little credit to the skill of their artists, while of their own science, good sense, and ardor in the promotion of rational improvement, they will descend to posterity as living memorials.

These gentlemen inform us that in our country, one hundred and forty different species of trees grow to the height of thirty feet, while in theirs, only thirtyseven grow to the same height, and that but eighteen of those are natives of their forests.

OAKS.

Among the numerous kinds of trees which in this as in every other country, load the earth with their wealth, the oak is the most extensive and most interesting genus. The different species of this tree, described by various authors, amount to one hundred and forty, one half of which are natives of America.

The numerous species of this genus possess almost every variety of character. They differ greatly in their magnitude and elevation; in the texture, strength, and durability of their timber, size, taste, and abundance of their fruit; the form, color, and odor of their leaves, and in almost every other property belonging to vegetables. While one species presents its stern and lofty head to the raging of the tempest, and protects from its fury the numerous trees of less hardy growth, others merely creep upon the earth, seldom rising more than twenty inches above its surface. The timber of one kind is almost as firm and durable as iron, while that of another is so loose and open in its texture as to be classed among the soft woods. The acorns of some oaks are large, extending far out of their cups, are palatable to many animals, and by some nations, especially by the natives of America, esteemed as food and even as delicacies, and are very abundant; while others are small, nearly covered by their envelope, of a bitter taste, and with but here and there one upon a tree. The leaves of some are small, others large; some smooth, others deeply indented; some of a

dark green, others of a light complexion ; some enriching their species with perpetual verdure, others deserting at the first annual frost, the parent stock which supported and nourished them through the summer, to the buffetings of every winter.

Accounts of several oaks hand them down to us as renowned in history. Some on account of their great size, others for their recording, or in some way preserving interesting events. One in Dennington Park, (England), called the king's oak, rose to the height of fifty feet, without a limb or knot, and squared five feet of solid timber. Another, called the queen's oak, was nearly the same size. An oak in Holt Forest was thirtyfour feet in circumference in 1759, and twenty years after, the circumference had not increased half an inch. Another extended its boughs one hundred and forty feet, and furnished twentyeight tons of timber. The Boddington oak, in the vale of Gloucester, was fifty-four feet in circumference at the base, with a hollow cavity of sixteen feet. Damory's oak, in Dorsetshire, the largest known, was sixtyeight feet in circumference, with a cavity of sixteen feet by twenty, and was used in the time of Cromwell for the entertainment of travellers. In 1703, it was shattered by a storm, and in 1755 the last vestiges of it were sold for fire-wood. An immense oak was dug out of the Hatfield bog, one hundred and twenty feet in length, twelve feet in diameter at the base, and six feet at the smaller end where it was broken off.

Less than a hundred years since, the oak against which the arrow of Sir William Tyrrel glanced before it killed William Rufus, was standing, though in a decayed state. Charles the Second concealed himself in an oak at Bascobell, after his defeat at Worcester. An oak still more renowned, is said to be standing in Stirlingshire, under which the Scottish patriot, Wallace, convened his followers, and impressed upon them the necessity of throwing off the yoke Edward was attempting to fasten upon them, and their power of freeing themselves from his thralldom. Alfred's oak, at Oxford, which was a sapling when that great monarch founded the university, is said to be still standing. An oak is still standing in Hartford, Connec-

ticut, under which was concealed the charter of the state given by Charles Second soon after it was received.

WHITE OAK.

The most valuable species in this genus of forest trees both in Europe and America is the white oak. Indeed, the timber of this tree is probably applied to a greater variety of uses in the domestic and useful arts and comforts, than any other vegetable growing upon our globe. In the character of this timber are combined solidity, strength, elasticity, durability, and an abundant growth, extending in this country in greater or less quantities from latitude 28° to 46° north. It is used to a great extent for the frames and coverings of houses, for almost all kinds of agricultural implements, such as wagons, carts, ploughs, and harrows, also for the posts of fences, and sometimes for boards; and except hickory it is the best fire-wood found in the northern states.

It is used in vast quantities for the staves of casks, fifty-three millions of which were exported to the West Indies, and the same article to the amount of one hundred and fortysix thousand dollars to England, in the year 1808, a part of which, however, were other species of the same genus than white oak. The same timber when young, on account of its elasticity, is extensively used for hoops, as it is for baskets and many other purposes where that property is required.

But perhaps the most extensive, if not the most important use to which this timber is applied, is the building of ships. In most of the ship-yards in the United States, the keel, frame, knees, planks, and many of the boards, for vessels of all sizes, are made of the timber of the white oak.

Though the American white oak bears a near resemblance to that of England and other parts of Europe, it is said to be less firm in its texture, less durable, and of course less valuable for most of the purposes to which it is applied. It hence cannot like many other American trees, be recommended for cultivation in Europe, but on the contrary the European oak ought to be introduced into our own forests.

The acorns of this species are large and sweet, of a grayish color, contained in a rough and shallow cup, but not abundant. The bark is white and rough, the leaves deeply indented, and by that means cut into large lobes ; many of them continue upon the tree through the winter, which circumstance is peculiar to this species.

LIVE OAK.

This singular and useful tree is confined to the southern sections of the United States. It has the most luxuriant growth on the islands, and near the creeks in the Carolinas, Georgia and Florida. Its northern limit is near Richmond, Virginia, and it extends from thence to the mouth of the Mississippi. Its numerous limbs, with their branching and irregular form, and the hardness and durability of the wood, render it the most valuable material that grows, for the building of ships. Its great importance to our navy, the narrow limits to which it is confined, and the great destruction it has suffered, to give place to the growth of cotton, have led Congress to take measures to preserve and cultivate it.

It is neither so large, or so high, as many other trees ; its common height being from forty to fiftyfive, and the diameter of the body from one to two feet. It has a broad tufted head, supported upon a trunk about eighteen or twenty feet high, and when seen from a distance, has some resemblance to an aged apple tree, or perhaps more like a pear tree. Its leaves are small, of an oval shape, not indented, of a dark green on the upper surface, and whitish beneath. They continue upon the tree several years, and fall but gradually, so that the tree always retains its rich and native verdure.

The acorns are of a long oval form, almost black, cups shallow with a gray color. The natives are said to have extracted an oil from them, which they used with their food, besides eating them in their natural state. They are abundant, some seasons particularly, and they germinate so readily, as sometimes to shoot out their radicals before they fall from the tree.

Few trees are probably more deserving of an extensive cultivation ; but doubts are entertained whether they can

be propagated, except in maritime regions; and it has even been supposed that sea air is essential to its existence.

CORK OAK.

The tree which furnishes all the cork used in the domestic and useful arts, is confined to the south of Europe and the north of Africa. It is an evergreen, though a great portion of the leaves fall every spring, giving place to fresh ones. They are oblong oval, of a light green above, and whitish beneath. Acorns large and half buried in their cups, of sweet taste, and palatable to some animals, especially swine. The timber of this tree is hard and compact, but less durable than the more common oaks.

The principal value of the cork oak is in the bark, which indeed constitutes the riches, in a great measure, of those countries where it grows naturally or by cultivation. Spain, Portugal, France, Italy, and some of the Barbary States, furnish the cork for commerce.

The first coat which is taken from the tree, when it is about fifteen years old, is of little value, being thin, hard, and full of fissures. The second coat, which is removed about ten years after, is valued but slightly. The bark is afterwards removed once in about eight or ten years, and every succeeding crop increases in value.

July and August, are the months for removing the bark, which is done by making incisions lengthwise of the body and two or three in a circular direction, by the application of wedges, hammers, &c. After the bark is removed, it is slightly charred to contract its pores, when by the application of weights to flatten its surface, it is prepared for market.

Two thousand five hundred tons of cork were imported into Great Britain in the year 1827. France is supposed to furnish seventeen or eighteen thousand quintals of cork annually, each quintal giving seven or eight thousand corks, amounting to a hundred and ten or a hundred and fifteen millions, most of which are consumed in that country. Michaux is of opinion, that the introduction of the cork oak into the United States, would prove a great acquisition to the country.

VARIOUS OAKS.

The species of oaks are too numerous to admit of a

particular description in this tract; a few others however, will be mentioned.

Black Oak is very abundant in various parts of the United States, and is extensively used for fuel and many purposes in the arts, and perhaps comes next to the white oak in the value of its timber. The bark of this tree is of great value, both in tanning and dying. It is one of the tallest trees in our forests, growing to the height of 80 or 90 feet.

Red Oak, like that last mentioned, grows to a great height and in great abundance, in the northern states. It produces acorns of a large size and in bountiful crops.

Scarlet Oak grows in the vicinity of Boston, and in other parts of the Union farther south, but not in Maine, New Hampshire or Vermont. It is a large tree and useful for numerous purposes.

Spanish Oak does not grow in New England, but is a large, abundant and useful tree in New Jersey, and States farther south. Its bark is particularly valuable.

Bear Oak, frequently known by the name of schrub oak, is very common in New England, but less known farther south. Its common height is three or four feet, and it sometimes grows to the height of eight feet. The small size of this tree, though it covers hundreds of acres of barrens in some regions, gives but little value to its growth.

Running Oak is the smallest species in this genus, seldom rising more than twenty inches from the earth, and is found in the Carolinas, Georgia and Florida.

Bartram's Oak is a single tree, growing on the farm of Mr Bartram, three miles from Philadelphia. It is about thirty feet high, and eight in diameter, and is the only individual known of that species.

Willow Oak, *Laurel Oak*, *Mossy Cup Oak*, *Chesnut Oaks*, of several species, *Post Oaks*, and numerous other kinds, grow in abundance in different parts of this country, but the occasion will not justify a description.

WALNUTS.

Next to oaks, walnuts are the most numerous species of trees in American forests. Two general divisions are

made of this genus, the one embracing two species, viz. the *Black Walnut* and *Butternut*; the other, all that large class of trees known by the name of Hickory. In several points, the black walnut and butternut bear a near resemblance, and when young can hardly be distinguished, the bark and leaves being almost precisely alike.

Their fruit is alike in having the outer husk in one connected piece, so that it cannot be removed without a fracture, in which they differ from all the species of hickory. The shape of the fruit of the black walnut, is almost perfectly globular, while that of butternut is oval.

The timber of both these species, is valuable for many purposes in the arts, and though somewhat alike in the texture and appearance, the walnut is preferred for most uses to which they are applied. Indeed, few kinds of timber growing in this country, are more extensively used, and better answer a great variety of purposes, than the black walnut. It is of great value in numerous kinds of cabinet work, and before the introduction of mahogany, it was perhaps more used in that work, than any other material. It is also used for ship-building to some extent, and answers well both for the knees and floors of vessels of various sizes. Gun-stocks are made of this timber almost exclusively, which use, at the national armories, especially those at Springfield and Harper's Ferry, furnishes a large market for the timber, which is supplied from Philadelphia.

The black walnut grows in great abundance in Pennsylvania, Kentucky, Ohio and other western States, and although it is not a native of New England, wherever it has been introduced there, it grows with great luxuriance, and might undoubtedly be cultivated in any of the northern States, with great success. It is perhaps an article of political economy worthy of attention.

This tree resembles the common English walnut, both in its timber and fruit. Where the two have been cultivated beside each other, as is the case in England, the American tree outstrips the other in its growth. By grafting the European, or rather the Asiatic walnut on to the American, we may obtain the fruit of one and the timber of the other.

The butternut, or as it is called at the south, the white walnut, grows well in Canada, and in every part of New England. The timber of this tree is of considerable value in the arts, and some specimens which have been put into cabinet work, nearly equal mahogany in beauty. As it is a hardy tree, and fitted to a northern climate, it is perhaps worthy of more extensive cultivation.

Hickory. — The most interesting species of that large class of walnuts, called hickories, is probably the shagbark; called also the shellbark, and scaly bark. The timber of this tree is more flexible and stronger than almost any other in this country, and consequently is peculiarly fitted to certain purposes, which cannot be answered by other wood of greater firmness and durability. It is much used for hoops, bows, and numerous other articles, which require great flexibility. It is more valuable for fuel than any other wood in the northern States, and though of rather a slow growth, on account of its great value in the arts and comforts of life, deserves cultivation.

The fruit of the shagbark walnut is preferable to any other except one, and besides that, is the only one which yields nuts of sufficient value to be sent to market. These nuts are very palatable and much used, especially in regions where they grow.

Another kind of hickory resembling that just mentioned, is the thick shagbark. It is difficult to perceive a difference in the tree or timber, but the fruit of the last is nearly twice as large as that of the other, with a shell so thick as not to be broken but by a heavy blow, and is far less pleasant to the taste, and consequently seldom used.

Pacane-nut is a species of hickory growing in Louisiana, Illinois, Missouri and other western States. It is a handsome tree, growing like the two last mentioned, to the height of seventy or eighty feet, and like them with timber, coarse grained, heavy and strong, and leaves from 12 to 18 inches in length.

The nuts are large, with full kernel, thin shell, an agreeable taste, very abundant, and exported in large quantities to the West Indies and different parts of the

United States. The growth is slow, but if they should be grafted into the black walnut or shagbark with success, their cultivation would be an object worthy attention.

The *Pig-nut*, has a productive growth, and furnishes timber of equal or greater strength, than any other species of the walnut. The fruit is small with a thick shell, not agreeable, and of our course of little value, except to reproduce its kind.

This tree grows through an extensive range, and south of Vermont and New Hampshire, is common in every part of New England.

Bitter-nut is a common tree in various parts of the United States. It rises to the height of seventy or eighty feet, and furnishes timber of some value, though of less than most of the species just mentioned. The nuts are small, with thin shells and disagreeably bitter.

It will be concluded from this slight description of a few species of the walnut, that they are an important article of the natural growth of the United States. Although the properties of the two general divisions in this genus, do not resemble each other, and of course the timber of each is fitted for different uses, all are of great value in the arts, and deserve both preservation and cultivation.

The hickories resemble each other in the size, form and general appearance of the tree, and in the quality, and of course the uses of the timber. The timber of each possesses great weight, strength and flexibility, but are all subject to rapid decay, when exposed to heat and moisture, and are attacked and nearly consumed by worms.

MAPLE.

Botanists have described fourteen species of maple, seven of which belong to America. They are among the most lofty and beautiful trees of our forests, and grow in great abundance over a large extent of territory. They extend on both continents to northern latitudes, and flourish well in the coldest, hardest soils.

The different species of maples are not only among the greatest ornaments of the forest, but are applied to numerous important uses in the arts.

The most stately and beautiful tree in this genus, is the *Sugar Maple*. This tree enters largely into the forests of the northern States, and grows nowhere in greater abundance than between the latitudes of 46° and 43° , which embrace Canada, New Brunswick, Nova Scotia, Vermont, New Hampshire and Maine. In some parts of New York and Pennsylvania, it is also common and abundant. It was estimated by Dr Rush, that in the northern parts of these two states, there were ten millions of acres containing the sugar maple, at the rate of thirty trees to an acre. In Virginia, the Carolinas, Georgia and Mississippi, it is seldom if ever found.

The sugar maple occupies a more extensive range of American territory, than any other species of this genus. It flourishes best on elevated, and even mountainous situations, and in moist soils, and is often found in company with beech, ash and birch.

This tree often rises to the height of seventy or eighty feet, though more commonly to fifty or sixty. The great height, extended branches, regular form, rich verdure, and neat appearance of the leaves, render it a most beautiful shade tree, and it well deserves to line the sides of all our streets throughout the Union.

The wood when first cut, is white, but by exposure for a short time, takes a rosy tinge. The grain is fine and close, and when polished, has a silky lustre. It is strong and heavy, but not durable when exposed to the weather. In Vermont, New Hampshire and Maine, where oak and chesnut are not common, maple timber is used in their stead, as it is more durable than beech, elm or birch. It is much used by cabinet and chair-makers, and to some extent by wheelwrights, for axletrees, spokes, lining the runners of sleds, &c. The sugar maple timber is also sometimes used for the frames of houses, keels and lower frames of ships, and many other purposes which do not expose it to sudden decay by alternate moistening and drying.

Two accidental forms are found in some specimens of the sugar maple, which are much valued and sought for by cabinet-makers, as they give beauty to their work. The first is an undulating form in the grain of the wood,

which in this and the red flowering species, constitute the *curled maple*; the second, which is found only in old trees in a sound state, is a singular appearance of small radiating spots, more or less thickly interspersed through the wood, and furnish the material called *bird's-eye maple*. These singular spots are more numerous near the sap than near the heart of the tree.

The cause which produces these singular appearances in this timber has never been satisfactorily explained. Both, however, are beautiful, and if brought from a foreign country, the furniture made from it would be prized as the richest specimens to adorn our parlors.

The sugar maple when cut at the proper season, and thoroughly dried, forms an excellent fuel, for which purpose it is exported from Maine in great quantities. The quantity of heat produced from a given bulk of this wood, though less than that from hickory, is greater than can be furnished from most of the hard woods.

The *ashes* procured from this species of the maple, are richer in the alkaline principle, and more abundant in quantity than those obtained from any other tree. They furnish a large part of the potash exported to Europe from New England and New York.

The *charcoal* procured from this wood and used in forges and domestic economy, is of the most valuable kind; and that made in Vermont, New Hampshire and Maine, is one fifth heavier, than that from the same tree in the more southern States; a proof that northern latitudes are fitted to the growth and firmness of maples.

The *sap* of the sugar maple furnishes no inconsiderable resource for the economy, the comfort, and even the wealth of our northern citizens; especially to those occupying regions newly settled.

The method of procuring the sap and forming the *sugar*, is simple, and nearly the same in most places where any is resorted too. The common process to collect the sap is to perforate the tree with an inch auger, in two places about four inches apart, and eighteen or twenty inches from the ground. It is found that a more abundant flow of sap is obtained from a shallow, than a deep hole. Into these holes, two tubes are inserted, which from the direc-

tion given the auger in boring, nearly meet at the outer ends. The tubes are made of elder, sumac or other shrub with a large pith, and conduct the sap into small troughs or buckets, from which it is conveyed to the camp, or the place where temporary preparations are made for boiling, &c. These preparations are little more than a boiler, containing from fifteen to fifty gallons, suspended upon a bar supported by crotches, at a convenient distance from the ground for building the fire; moulds to receive the syrup when of sufficient consistence to form into cakes; and an axe for preparing the fuel.

The evaporation is carried on by a constant and brisk boiling of the sap, which is frequently replenished as the bulk is diminished, until a syrup is formed of sufficient strength to become solid as it cools. A scum which is constantly rising to the surface during the first part of the process is frequently removed, and before the syrup is left to cool and harden, it is strained through woollen cloth to separate the remaining impurities. The time for stopping the evaporation is determined by rubbing a drop of the syrup between the fingers, which will granulate if the process has been carried to a sufficient length. When the ebullition is so violent as to give signs of rising over the sides of the boiler, it is quelled by a piece of lard, butter, or rind of pork.

Maple molasses is made by discontinuing the evaporation before the liquid is of sufficient consistence to consolidate by cooling, and by the drainings from the syrup as it forms into sugar. Sugar of the finest character and grain may be formed from the sap of the maple, and though the more common kind is neither very white, nor very delicate, it has a peculiar flavor, much admired by those not accustomed to its use.

The time for collecting the sap is about the last of February, and continues from four to six weeks; after which the liquid is less abundant and less rich in the saccharine principle, and is finally so weak, that it can no longer be reduced to sugar. The tree gives the most abundant discharge of its sap, early in the season, and in clear pleasant days, preceded by cold frosty nights.

The quantity of sap discharged from a tree of an average size, varies in different years and different days.

Trees are sometimes supposed to average about four pounds of sugar in a season, but frequently do not produce more than half that quantity. A single tree discharges in one day from two quarts, to two or three gallons of sap.

The following statement appeared some years since in the Greensburgh, Penn. Gazette. 'Having introduced,' says the writer, 'twenty tubes into a sugar maple, I drew from it the same day, twentythree gallons and three quarts of sap, which gave seven pounds and a quarter of sugar. Thirtythree pounds have been made this season from the same tree, which supposes one hundred gallons of sap.' From this statement, it appears that but little more than three gallons were required for a pound, though four gallons are commonly allowed.

Maple sugar is made in most of the northern and western States, and in Canada; and it has been supposed that New York and Pennsylvania contain maples enough to supply the consumption of sugar in the whole of the United States. But as a country becomes settled, the groves and forests of maple disappear, and the expense of converting the sap into sugar is increased; so that the whole country will, within a moderate period of time, be supplied with this useful article in domestic economy, from foreign importations, or from the juice of the cane in our own country.

Though the ease and abundance with which sugar is made from the cane, and the expense of fuel to procure it from the sap of the maple would not favor the cultivation of this stately and beautiful tree for the supply of our tables, the value of its timber, and the elegant and cleanly shade it furnishes, would probably render the cultivation of it, especially by the sides of our roads, an article of domestic and political economy, as well as a public ornament and comfort.

Most kinds of domestic animals are excessively fond of the sap of the maple, and frequently break through their inclosures to get access to the vessels containing it.

If the sap be exposed for a few days to a warm sun, it is formed into vinegar of a good quality. Maple beer, which is a pleasant beverage, is also made from the same material, by the addition of yeast and the essence of spruce.

Besides the tree just described, several others of the same species are worthy of a fuller notice, than can be given on the present occasion.

The *Red Flowering Maple* makes its first appearance at the north in Canada, latitude 48° ; becomes more abundant in proceeding south, and is common to the extremities of Florida and Louisiana. Of all the trees which grow in wet grounds, and those occasionally overflowed, this flourishes most in the middle and southern States. It lines the borders of creeks, and abounds in swamps frequently inundated, and always miry. In these situations, it is found in company with black and white ash, swamp white oak, shagbark, hickory, and two or three other trees less commonly known. It is remarkable that this species of maple is also found in the vicinity of Pittsburgh on elevated ground. But in swamps it has the most abundant and largest growth, where it rises to the height of seventy or eighty feet.

The timber of this tree, like that of the sugar maple, is used in various kinds of cabinet work; and though less hard than that, it is more so than most other species of this genus, and of a closer, finer grain; and is hence readily wrought in the lathe, and polishes with a glossy silken surface. It finds an extensive use in the manufacture of chairs and cabinet work, and was formerly a common material for spinning-wheels.

The curled maple, much sought for by cabinet-makers, is furnished in greater abundance from this species, than that already described. Before the introduction of mahogany, it was more extensively used than at present, and is now used for inlaying mahogany, and other materials. For the stocks of fowling-pieces it is much used, for which purpose its lightness, together with its strength and elegance, renders it peculiarly appropriate. It is but poorly fitted for fuel, and is but little used for that purpose.

The French Canadians use the sap of the red flowering maple for sugar, though it produces but half the quantity of that from the species which produces this article of domestic economy in so great abundance.

The inner part of the bark of this tree, is used as a

dye stuff, which, with copperas, produces a dark blue ; and with the addition of a little alum, a black.

Notwithstanding the timber, from this species of maple, furnishes an elegant material for cabinet work, and is useful for many purposes in the domestic and common arts, it is so subject to decay, and to be devoured by worms, and to some other objections, that it will rapidly give place to the cultivation of plants of smaller growth, and will be less likely to be renewed than oak, ash, walnut, and many other trees.

The *White Maple* grows in Maine and Vermont, though it does not flourish so well under the rigorous winters of these states, as in more southern climates. On the banks of the Ohio it grows in abundance, and with great majesty and beauty. Its numerous extended branches, the richness of its foliage, interspersed with that of the willow, the brilliant white of its leaves beneath, forming a striking contrast with the bright green above, with an alternate reflection of both surfaces from the water which it overhangs, increases in no small degree the beauty of the landscape on this majestic river.

It is remarked that this tree, unlike others of the same genus, flourishes only on the banks of rivers with limpid waters and gravelly beds, and not in swamps and other miry soils or moist grounds.

The flowers of the white maple open early in the spring, are small and sessile, (closely set to the stem,) and produce fruit with two capsules, larger than those of most other species of this genus.

The wood of this tree is white and of a fine grain, but is softer and lighter than those of any other maple in the United States ; and from its want of strength and durability, is but little used in the arts. It is, however, occasionally used as a substitute for poplar for wooden bowls, and for some part of cabinet work, when a better material cannot be procured. Charcoal formed from this wood, is much used and valued by hatters, as it affords a more uniform heat, and of longer continuance than the coal of any other wood.

The sap is sometimes used for sugar, and produces about the same quantity as the red flowering maple,

which is only one half of that from the sugar tree. The sap begins to discharge from the tree in January, and discontinues before the other appears.

From the great majesty and beauty of the white maple, together with the rapidity of its growth, it has become, in Europe, the subject of extensive cultivation in gardens.

Black Sugar Maple. A tree somewhat resembling the sugar maple, and frequently mistaken for it, grows in Virginia, Pennsylvania, New York, and the southern part of New England. In the Genesee country it constitutes a large part of the forests, and yields an abundance of rich sap, which is much used in the manufacture of sugar. Its foliage is much darker than that of the sugar maple, and is hence called the *black sugar tree*. The shape, size and situation of the leaves, flowers and seeds, are much the same as those of the species for which it is frequently taken. The wood, though coarser grained, and less brilliant when polished than some other maples, would probably find a more extensive use in the arts, did not oak, walnut, and other valuable timber grow in abundance where this is found.

Sycamore Tree. A species of maple, known by the name of sycamore tree, is diffused over the centre of Europe, and abounds in Bohemia, Hungary and Poland. It is a majestic and beautiful tree, rising to the height of sixty or seventy feet, with a regular form, and leaves of a dark green above, and whitish beneath. In the heat of midsummer they are covered by a sweet viscid substance, collected with avidity by bees.

The wood of the sycamore is fine grained, and susceptible of a beautiful polish. It is much used by turners, frequently for making violins, and sometimes for ornamenting forte pianos. A course of interesting experiments has proved it to be capable of affording more heat than any other tree in the north of Europe.

Sugar has recently been made from the sap of the sycamore in Bohemia and Hungary, though it does not yield it in so great abundance as the American sugar maple.

Norway Maple. Another lofty tree in the forests of Europe, accompanies the sycamore; but as it abounds

most in Sweden and Norway, it has received the name of Norway maple. Its appearance and uses so much resemble the species last mentioned, that a particular description is unnecessary.

Moose Wood. In the British provinces in America, in New England, and in small quantities farther south, a small species of maple constitutes a large portion of the underbrush in many of the forests. It seldom grows to more than ten feet in height, and four or five inches in diameter. The light color and fine grain of the wood, bring it into use in some of the smaller work of cabinet-makers, but its small size will prevent an extensive application of it in the useful or domestic arts.

This is one of the first trees to announce the approach of spring. This circumstance, together with its rapid growth, and thick and beautiful foliage, has brought it into extensive cultivation in the parks and gardens of Europe.

The principal use made of it in America is the browsing of cattle at the opening of spring, when the buds are swollen, the twigs tender, and rich in saccharine matter. At this time the various kinds of domestic animals, as well as the moose and other animals in the forest, feed upon the buds, twigs and branches of this tree with avidity. The first settlers observing the rapidity with which this tree was devoured by moose, then abounding in the forests, gave it the name of *moose wood*, which it has ever since retained.

BIRCHES.

No tree of the forest rises with such majesty in northern climates as the birch. It is found as far north as the seventieth degree of latitude, though under the intense cold to which it is there exposed, it appears only as a shrub. A few degrees farther south, it rises to the height of seventy or eighty feet, and between the sixty-fifth and fiftyfifth degrees of latitude, is the tallest and hardiest of the trees which compose the forests.

On the other continent, Russia, Sweden, Norway and Lapland are the countries where the different species of birch abound; on this continent, Canada, the New Eng-

land states, and northern regions generally, are congenial to the growth of this vegetable, where it is more common than in countries farther south. As maples, elms and beeches increase, birches diminish both in number and size. The fortyfifth degree of latitude is the northern limit of this genus of forest trees in Europe: in this country it is found in latitudes considerably farther south, though here, it is seldom found in Virginia, and never in the more southern states.

Seven species of birch have been discovered in American forests, and about the same number in those of Europe. Among these species, there is a less variety than in some other trees; though they differ considerably in their size, and more or less in the qualities of their timber.

The *Canoe Birch* is the most common tree of this genus in Canada, New Brunswick, Maine, New Hampshire and Vermont; but it is not known in the southern part of Connecticut, nor in New York, south of Albany.

This tree grows to the height of seventy feet, and three feet in diameter. The wood has a fine glossy grain, and considerable strength, but soon decays when exposed to the weather. It is much used in cabinet work, for many articles in which it is a beautiful material.

On trees not more than six or eight inches in diameter, the bark is perfectly white, like that of the white birch of Europe, and like that, too, it appears to be almost indestructible. This bark is applied to various uses, some of which are important. It is sometimes placed beneath the shingles on the roofs of houses; baskets, boxes and port-folios are made of it, and embroidered with silk; it has been used as a substitute for paper, and is sometimes placed between the soles of shoes, and in the crowns of hats, as a protection against moisture.

The most important use to which the bark of birch is applied, is in the construction of canoes, from which this tree derives its name. The bark is removed from the tree in the spring, in strips from two to nine inches wide, and ten or twelve feet long. These strips are stitched together by the fibrous roots of the white spruce.

The seams are coated with resin from the Balm of Gilead.

These canoes are much used both by the Indians and French, in their long journeys into the interior. They are sometimes of sufficient size to carry fifteen passengers; and one capable of carrying four persons, with their baggage, weighs but forty or fifty pounds.

The canoe birch has been introduced into the nurseries in France; and as it grows to a large size on poor land, and surpasses the European birches in the qualities of its timber, Michaux is of opinion, that it can be introduced to advantage into the forests of Europe.

White Birch. This species of birch, like the one last mentioned, grows in Canada and the New England states, and is sometimes found as far south as Virginia. It is neither so large nor so abundant as some other species of this genus. It is most common on thin soils, not occupied by many other trees, where it grows to the height of thirty or thirtyfive feet. The wood is white, soft, and of a glossy lustre; but the small size of the tree, and the rapid decay of the timber when exposed to the weather, prevent its coming into use, either in the arts, or for fuel.

Red Birch. The climate and soil of the southern states appear to be congenial to this species of birch. It flourishes well in the Carolinas, and even in Georgia, but is seldom, if ever, found north of New Jersey. It is not, like other species of birch, found in forests or thickets of other trees, but on the banks of rivers, accompanied by the button-wood, white maple and willow. It flourishes most on the sides of limpid streams with gravelly beds, where it grows to the height of seventy feet.

The wood of the red birch is sufficiently compact, hard and beautiful to fit it for a variety of uses, not unlike those to which the other species are applied.

The *Yellow Birch* abounds most in those climates and soils where the canoe birch prevails. It is a beautiful tree, and rises to a great height. The trunk is straight, nearly of the same diameter, and frequently without branches to the height of thirty or forty feet. It is remarkable for the golden yellow color of the bark, from which is derived its name.

The wood is used for many kinds of cabinet work ; and experience has proved it to be well fitted for those parts of the frames of vessels which are always under water. It is also an excellent fuel.

Black Birch. The beautiful foliage, and the valuable properties of the timber of the black birch, render it one of the most interesting species of this genus of forest trees. It is found over an extensive territory, growing in abundance from Canada to Maryland, and in elevated or mountainous regions, even in Georgia. On the Hudson River, and in New Jersey it is one of the first trees to announce, by the opening verdure of its foliage, the advancement of spring. The growth of this tree is rapid, its foliage beautiful, and its timber no less useful than any other species of birch. From these considerations, Michaux recommends to Americans great care in the preservation of it, and to Europeans the introduction of it into their forests

The sap of the birch which flows in great abundance in the spring, is used for making a syrup, and may be converted into beer, vinegar, and a kind of wine, but not into sugar. The leaves, both in a green and dry state, are used for the feeding of cattle.

All the properties of the common white birch of Europe, are united in the canoe birch of our own country.

Although this genus of American forest trees is less useful and less interesting than some others which adorn and enrich our country, it constitutes a part of the beauty and the riches of this highly favored part of the globe, and deserves to be studied more and appreciated higher, by those into whose possession it has fallen.

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	S. C. Stevens.	PENNSYLVANIA.	
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SCIENTIFIC TRACTS.

NUMBER IX.

THE WEATHER.

THE eye, as christian philosophers have often shown, is an optical instrument, contrived for its purpose with wonderful dexterity. The whole human system is a highly artificial machine, filled with evidences of inventive skill: and the whole animal and vegetable creation is crowded with the most consummate proofs of contrivance, mechanical and chemical, for adapting means to ends, and for accomplishing those benevolent purposes which the Creator has in view.

There is not, however, in the whole range of human observation, any case in which this benevolent design, and this unrivalled skill in the selection of means to promote it, is more striking than in that arrangement in the constitution of nature, which produces those phenomena, to which, as a class, we give the appellation of THE WEATHER. These proofs are not at once so evident; and when we examine them, we find them so unlike any human contrivances that we do not so easily appreciate them. The telescope imitates the eye; the automaton, made by the highest effort of human skill, gives us a faint resemblance of muscular motions: and in many other cases where human ingenuity has imitated the Creator's works, we can more easily see the power and wisdom displayed in the original, because we can appreciate the efforts made to produce the copy. But in regard to those phenomena which are now our subject, the Creator's work stands uncopied and alone. There is no human imitation of the whirlwind and the storm. There is no power or skill among us which can guide the lightning or arouse the tornado. Hence we have nothing to rest upon in endeavoring to ascend to proper concep-

tions of the divine wisdom and power displayed in these phenomena.

If we, however, look at the circumstances, we shall, in a degree, be able to understand the subject. Let us suppose that the earth had been completed in its present form and condition, but without an atmosphere. The ocean lies calm and still : the fields and hills are moistened with water, and consequently crowned with verdure and fertility ; — for we must suppose that at the time when the creation is completed, there is a proper distribution of heat and moisture for the *commencement* of those processes which give to earth its beauty and fruitfulness. Fountains therefore spring forth among the hills. Cataracts descend from every precipice, brooks meander through the valleys, and their united waters flow on in the majestic river. In fine, the whole earth is, at the moment, precisely what it is now, presenting every variety, from the drenched meadow to the warm soil of the elevated plain.

But all is still. As we suppose no *atmosphere*, there must be no *breeze*, and the whole creation must sleep in apparent death. No bird can fly ; and if we suppose that Providence has arranged it so that human life can be preserved without the air, man would observe, as he walked around, one universal silence and stillness, of which no calm summer's evening can now give us any conception. The ocean must present one broad, glassy expanse, unruffled by any wave, unless the entrance of some mighty river should send forth a few silent ripples. No leaf would rustle or move ; not a blade of grass would wave, and not a sound would arise from nature, or animal, or man. The lion might strive in vain to roar, and the lofty cataract would fall upon the rocks *silently*.

But this dreadful calm would not be all. As the brooks and streams could carry their waters unceasingly to the ocean — that great home of the waters — there would be no means of again supplying their fountains. The spring from the hill side would soon be checked in its flow ; the cataract grow slender in its form, and at last cease to fall ; the southern sloping hill would soon become brown, and nature, from every elevated spot, would soon call for water. But it must call in vain. Gravitation

would hurry with irresistible energy every brook and stream onward in its course, and ere long the work would be done. Every fountain would have failed ; river after river would have left its bed deserted and dry. The meadows and marshes would be drained ; the waters of every lake and pond would have escaped, and men might walk over the dry and dusty bed even of Niagara.

The consequences to animal and vegetable life need not be described. It requires very little imagination to see that our lovely earth would soon reduce itself under these circumstances to one universal desert ; upon which every plant and every land animal must have found a grave.

And what was the plan which the Creator adopted in order to avoid this danger ? He spreads over the whole surface of the earth an ATMOSPHERE, *transparent, invisible*, but producing almost inconceivable effects. It raises the waters from the ocean, whither they are constantly tending, and by its unceasing motions they are borne back to the land where they descend in repeated showers. By this arrangement, the great object is accomplished, but it is not by a regular and monotonous process. There are a few simple principles, but they produce an infinite variety of effects.

The plan which will be adopted in this treatise will lead me, in the first place, to detail those general principles upon which all the particular phenomena depend. They are few and simple in character.

1. TEMPERATURE OF THE AIR.

(a) *Diminution of Heat from the Equator towards the Poles.*

Owing to the manner in which the rays of the sun fall upon the different regions of the earth's surface, there is a gradual diminution of heat from the intense, and sometimes unmitigated sultriness of the equatorial regions, to the severe and perpetual cold of the poles. The following interesting description of a scene near the southern pole will give the reader a very vivid conception of the nature and effects of this cold.

The individuals mentioned in the account belonged to Capt. Cook's celebrated expedition to the Pacific Ocean.

It must be noticed, too, that this took place in the *summer* of those latitudes; i. e. in January, corresponding to our July. The party, consisting of Sir Joseph Banks, Dr Solander, and ten attendants, were returning from a botanical excursion, and Dr Solander had just been cautioning the company against indulging in a propensity to sleep. The account proceeds as follows :

‘They had not proceeded far before the effects apprehended began to be felt; and he, who had thus cautioned others, was the first to declare himself unable to observe his own precept. At length, overcome by a stupor, he threw himself on the ground, although it was covered with snow. A black servant of Mr Banks, named Richmond, next yielded to this fatal propensity. In this distress, five of the company were sent forward to make a fire at the first convenient place they could find, while the rest continued with the doctor, making use of every means to keep him awake. The poor negro was so overcome with fatigue that being told he must keep in motion or he would be frozen to death, replied that he desired only to lie down and die! At length, all the endeavors of the company became ineffectual. Their whole strength was not sufficient to carry their two exhausted companions, so that they were suffered to sit down, and in a short time they fell into a profound sleep. In a few minutes afterwards news was brought that a fire was kindled at the distance of about a quarter of a mile. Dr Solander was then waked with great difficulty; but during his short sleep his muscles were become so contracted that his shoes fell off his feet, and he had almost lost the use of his limbs: but all attempts to wake the servant were ineffectual. Two men, who seemed to have suffered the least by the cold, were left to look after him, and in a short time two others were sent to their relief. One of the former rejoined the company, but the other was quite insensible. Their companions, therefore, made them a bed of boughs, and spread the same covering over them to a considerable height, and in that situation left them to their fate.

‘The company passed the remainder of the night in a dreadful situation round the fire. They supposed them-

selves at a great distance from the ship; their way stretched through a trackless wood, and they were unprovided with refreshments, their only provisions being a vulture, which they had shot in the course of their journey. Nor did the dawn of day remove their apprehensions; for at the approach of light nothing presented itself to their view but a dreary expanse of snow. It was not till six o'clock in the morning that they could discover the place of the sun through the clouds, which then began to disperse. With foreboding apprehensions they went in search of poor Richmond and the other man, whom they found quite dead. A dog, which belonged to one of them, was however still alive and standing close by his master's corpse, which he unwillingly left to follow the company. The hardy nature of this animal enabled him to brave the severity of the weather, and he was for several years afterwards alive in England.'

This diminution of heat is, however, by no means regular. Different countries—equally distant from the equator—are very different in climate, according to their situation. The average warmth of the atmosphere at any place is learned by keeping, for a long time, a record of the weather and obtaining the mean of all the observations. There is another method somewhat singular: that is, to take the temperature of *the springs of water*. These it is supposed come from such a distance below the surface of the ground that they are not affected by the ordinary changes of heat and cold in the atmosphere above, and they are accordingly found to remain nearly the same during the year. In making such observations, however, a proper regard must be had to the situation of the springs, the strata through which they come, and their elevation above the level of the sea.

(b) *Diminution of Heat from the Surface of the Earth upwards.*

Although this fact is very generally known and acknowledged, the cause of it is not very obvious. An observer at the equator, in the middle of a sultry summer's day, might perhaps imagine that if he were to ascend

into the atmosphere, *directly towards the sun*, it would grow warmer the farther he proceeds. It is not, however, the fact. Whether he mounts in a balloon or ascends a mountain, he finds the *cold increases* as he leaves the surface of the earth, until he arrives at a region of perpetual ice and snow. The cause is this.

Suppose we take a sponge, compress it slightly with the hand, and pour upon it as much water as it will receive. While it is now dripping with the surplus, release the pressure. The pores will immediately open, and they will be more than sufficient to absorb the water, so that the sponge, in its expanded state, will be comparatively empty. So if the experiment is reversed. If a sponge is moderately wet, while in its expanded state, and afterwards compressed with the hand, it will be found that it cannot retain the water which at first it received.

Now the *air* is this sponge, compressed near the surface of the earth by the load of atmosphere which is above it; and the heat which it contains is represented by the water, which was abundant in the compressed, and scarcely perceptible in the expanded sponge. If a portion of this air, thus compressed at the surface of the earth, and containing an abundance of heat, rises, it expands, and occupies a larger and larger space: *the quantity of heat, therefore, which it contains, is diffused over a greater space*, and consequently will produce less sensible effects. In the same manner, if a portion of the air, in an elevated region, having a moderate quantity of heat diffused throughout it, should *descend*, it will become *compressed* as it approaches the surface, and the heat which it contains, which before occupied a great space, will now be condensed into a small one, and will produce more sensible effects. In other words, the air will become warmer. These motions of the air, ascending and descending, are continually taking place, and they keep up a constant difference in temperature of the higher and lower regions.

Arnott, in his interesting work on Physical Philosophy, makes the following remarks:—‘Persons not understanding the law which we are now illustrating, will express surprise that wind or air blowing down upon them from a

snow-clad mountain should still be warm and temperate. The truth is, that there is just as much heat combined with an ounce of air on the mountain top as in the valley; but above, the heat is diffused through a space perhaps twice as great as when below, and therefore is less sensible. It may be the same air which sweeps over a warm plain at the side of a mountain, — which then rises and freezes water on the summit, — and which in an hour after, or less, is playing among the flowers of another valley, as a warm and gentle breeze.'

2. CURRENTS OF THE AIR.

(a) *Great Current from East to West.*

It is well known that near the equator there is a constant wind blowing from east to west. This is called the Trade Wind; and its regularity is such as is difficult for us to conceive, who live in a country where the variableness of the wind is proverbial. Through the Indian, Atlantic, and Pacific Oceans, this wind blows almost unceasingly. It is interrupted by the land in many places, and in different seasons it blows with greater or less degrees of violence. North and south of the equator, too, it changes from an east to a northeast and southeast wind.

The cause of this wind is the following. Let N S

represent the poles, and E Q the equator. Now a portion of air at *a*, revolving with the earth in the direction of the arrow, moves at the rate of about ten miles an hour; whereas another portion at *b*, upon the equator, moves at the rate of fifteen miles an hour, on account of its revolving in a greater circle. Now in

consequence of the heat upon the equator, the air is rarefied and rises, and the air from *a*, comes down to supply the vacancy. It has however an eastward velocity of only ten miles, while that part of the earth to which it

comes is moving much more swiftly. It will of course *be left behind*. In other words *it will appear to move towards the west*. This is the explanation of that great aerial current which is constantly flowing from east to west over all the equatorial regions.

The Gulf Stream is one remarkable consequence of this wind: and another, quite as striking, is seen in its effects on the nature and length of sea voyages, and the tracks of ships. These winds are so regular that seamen sometimes go much out of their direct course to meet or to avoid them; and persons not aware of this fact are much surprised in reading accounts of voyages to find the ships, whose adventures they are following, sometimes very far from the track which it might have been supposed they would pursue.

(b) *Monsoons.*

In various parts of the earth, within the tropics, there are periodical winds which blow six months in one direction and six months in the opposite. They are called Monsoons. It is unnecessary for our present purpose more particularly to describe them, than to say that they prevail most extensively in various parts of Asia, and especially in the northern part of the Indian Ocean. When they change in the spring and autumn, the winds are for some time variable and violent, and the aspect of the sea and skies very unfavorable to navigation.

(c) *Land and Sea Breezes.*

In warm climates there is on the shore of the sea a breeze blowing towards the land in the night, and towards the sea in the day. The cause is obvious. The land becomes heated by the sun, and the air rises from it, and a fresh supply comes in from the sea to fill the vacancy; for the sea, not reflecting the sun's rays so strongly, does not heat the air over it so soon. In the night, however, the current is reversed. The land becomes cooler than the sea, and the atmosphere moves from the warmer to the cooler region. The following very happy illustration of this process has been quoted many times in books on this subject. It is so clear and complete that it deserves to be perpetuated.

‘Take a large dish, fill it with cold water, and into the middle of this put a little plate filled with warm water, the first will represent the ocean, the latter an island rarefying the air above it.

‘Blow out a wax-candle, and if the place be still, on applying it successively to every side of the dish, the smoke, being visible and very light, will be seen to move towards the plate, and, rising over it, point out the course of the air from sea to land. Again, if the ambient water be warmed and the plate filled with cold water, when the smoking wick of the candle is held over the centre of the plate, the contrary will happen, and show the course of the wind from land to sea.’

(d) *Variable Winds.*

In the Temperate and Frozen Zones on each side of the equator, the winds are variable. Great efforts have been made to study their changes so as to predict the weather; but these efforts have been almost entirely fruitless. There seems to be some faint connexion between the changes of the moon and those of the wind. Whether this arises from any influence of the moon itself, or of the tides of the ocean, occasioned by the motions of the moon, or of the great *Aerial Tides*, which, though not obvious to us, are equal, real, and certain, is a point on which the weatherwise are not agreed. We shall make no farther remarks on this point but only present our readers here with one or two descriptions of violent winds which have occurred in the latitudes in which we live. The following account of a hurricane in Huntingfordshire, Sept. 8, 1741, is unquestionably true.

‘The storm seemed not to be thirty yards high from the ground, bringing along with it a mist, rolling along with such incredible swiftness, that it ran about a mile and a half in half a minute. It began exactly at twelve o’clock, and lasted about thirteen minutes, eight minutes in full violence: it presently uncovered the house, and some of the tiles falling down to windward, were blown in at the sashes and against the wainscot on the other side of the room. The broken glass was blown all over the room; the chimneys all escaped, but the statues on

the top of the house, and the balustrades from one end to the other, were all blown down.

The stabling was all blown down, except two little stalls. All the barns of the parish except those that were full of corn quite up to the top, were blown flat on the ground, to the number of about *sixty*. The dwelling houses escaped best, there were not above twelve blown down, out of near one hundred. If the storm had lasted five minutes longer, almost every house in the town must have been down; for they were all in a manner rocked quite off from their underpinings. All the mills in the country were blown down. Hay-stacks and corn-stacks were some quite blown away, some into the next corner of the field. Wherever it met with any boarded houses, it seemed to exert more than ordinary violence on them and scattered their wrecks about a quarter of a mile to the northeast in a line. 'I followed,' says the gentleman who furnished the account, 'one of these wrecks; and about 150 yards from the building, found a piece of a rafter, many feet long, and about six inches by four, stuck upright two feet deep in the ground. At the distance of 400 paces from the same building, was an inch board, nine inches broad, fourteen feet long; these boards were carried up into the air, and some were carried over a pond about thirty yards; and a row of pales as much as two men could lift, were carried two rods from their places, and set upright against an apple tree. Pales in general were all blown down, some posts broke off short by the ground, others torn up by the stumps. The whole air was full of straw; gravel stones as large as the top of my little finger, were blown off the ground in at the windows; and the very grass was blown quite flat on the ground. After the storm was over I went out into the town, and such a miserable sight I never saw; the havoc above described; the women and children crying; the farmers all dejected; some blessing God for the narrowness of their escape, others wondering how so much mischief could be done with one blast of wind, which hardly lasted long enough for people to get out of their houses. The storm was succeeded by a profound calm, which lasted about an hour, after which the wind continued pretty high till ten o'clock at night.'

How such sudden and violent gusts of wind are to be accounted for is not satisfactorily ascertained. They are much more frequent in mountainous and in tropical countries, than in other parts of the earth.

The following statement may be relied upon as fact. The account was furnished for this treatise by an eye witness.

Hurricane in the West Indies.

‘ In the fall of the year 1780, a very severe hurricane visited the westerly part of the island of Jamaica. In the morning of the day which was so destructive, the sky was cloudy, and the clouds wild in their appearance; the wind from the north and east. About one o’clock, while at dinner, the wind was so violent as to blow down one of the negro houses, and in a short time the rest of them in succession. After this, a building, containing the cane after the juice is taken from it, was blown down in like manner. Aware of our own danger, every measure was taken to secure the doors and windows, knowing that our own security depended upon preventing the wind entering the house. For a few hours we succeeded; but at last a door or window was blown in; and in a very short time the whole of the house, excepting the southwest room, was blown away from the ground floor. Before this, however, we had made our escape out of the southerly door, and sought our protection behind another building, to the southwest of the house, where we remained till about midnight. The wind then subsided, and there was an appearance of entire calm; we availed ourselves of this to return to the southwest room, and to put on what dry clothes we could collect, but before we had completed this, the storm was renewed, and blew with equal violence as before from the south and west, and carried off the remaining room, and exposed us, without protection, to its fury; our only resource was the cellar, which, with great difficulty, we reached; every building on the estate was destroyed, and the roads rendered impassable for ten days. A remarkable circumstance occurred on an adjoining estate: the buildings on this estate were placed at the foot of two hills, with a

deep gully between the hills. A plank windmill was exposed to the wind, which came down this gully, and with such violence as to carry a shingle from a distant building in such a direction as to enter the plank of the windmill three quarters of an inch; a piece of the plank, with the shingle in it, was put on board the *Ville de Paris*; to be deposited in the British Museum. The *Ville de Paris* was lost, and with it the evidence of this fact.

The swell of the sea was so great from the violence of the wind, that a ship of about four hundred tons was carried on the land about eighty rods from the shore; this was the only habitation for many of the distressed inhabitants of Savanna le Mar till they could rebuild. There were many almost miraculous escapes; and farther scenes of distress which it would be difficult to describe.'

The variable winds which blow in different parts of the earth, are sometimes productive of very striking effects, owing to peculiar circumstances. If the current comes from a dry and sandy country it is of course dry and scorching; — and the reverse. There is the hot sirocco, — the damp and chill east wind of New England; — the refreshing sea breeze; — and the fatal simoom. We shall give but one specimen of these; — it is the harmattan, a current which derives a drying and withering influence from passing over the arid sands of Africa. It blows from the interior towards the western coast.

'Extreme dryness is an extraordinary property of this wind. No dew falls during the continuance of the harmattan; nor is there the least appearance of moisture in the atmosphere. Vegetables of every kind are very much injured; all tender plants, and most of the productions of the garden, are destroyed: the grass withers and becomes like hay; vigorous evergreens likewise feel its pernicious influence; the branches of the lemon, orange, and lime trees droop, the leaves become flaccid, wither, and, if the harmattan continues to blow for ten or twelve days, are so parched as to be easily rubbed to dust between the fingers. The fruit of these trees, deprived of its nourishment, and stunted in its growth only *appears* to ripen, for it becomes yellow and dry, without acquiring its usual size. The natives take the opportu-

nity afforded by the extreme dryness of the grass and young trees, to set fire to them, especially near their roads, not only to keep the roads open to travellers, but to destroy the shelter which long grass, and thickets of young trees would afford to skulking parties of their enemies. A fire thus lighted flies with such rapidity as to endanger those who travel. A common method of escape is, on discovering a fire to windward, to set the grass on fire to leeward and then follow your own fire. There are other extraordinary effects produced by the extreme dryness of the harmattan. The covers of books even closely shut up in a trunk, and lying among clothes, are bent as if they had been exposed to the fire. Household furniture is also much damaged; the pannels of doors and of wainscot split and any veneered work flies to pieces. The joints of a well laid floor of seasoned wood open sufficiently to lay one's finger in them; but become as close as before on the ceasing of the harmattan. The seams also in the sides and decks of ships are much injured, and the ships become very leaky, though the planks are two or three inches in thickness. Iron bound casks require the hoops to be frequently driven tighter; and a cask of rum or brandy with wooden hoops, can scarcely be preserved; for unless a person attend to keep it moistened, the hoops fly off.

'The parching effects of this wind are likewise evident on the external parts of the body. The eyes, nostrils, lips and palate, are rendered dry and uneasy, and drink is often required, not so much to quench thirst, as to remove a painful aridity in the fauces. The lips and nose become sore, and even chapped; and though the air be cool, yet there is a troublesome sensation of prickling heat on the skin.'

(c) *Force of Winds.*

This instrument by which the force and velocity of winds is measured is called a wind gage, or anemometer. It is constructed as follows. A B C E is a bended tube, large at A, which side is to be turned towards the wind. The part F B C E is filled with water or some other liquid less likely to freeze, and the whole apparatus is

supported in such a manner by the stand *D*, as to turn with the wind, so that the orifice *A* is turned *towards* it. The pressure of the breeze now upon the surface of the water at *F*, forces it down in the great tube, and consequently up in the small tube, *C E*. The height to which it rises may be observed on the scale at *E*, and indicates the force of the wind. The tube at *B C* is made very small, in order to prevent sudden fluctuations of the surface of the water at *E*. The force and velocity of the wind may both be obtained with a good degree of accuracy by this instrument. The drawing is, however, not intended to be an accurate delineation of the instrument, but only a sketch, illustrating its construction.

The following Table will give the reader some idea of the velocity of different winds, and the force which they exert upon the surfaces which they press :

Miles per Hour.	Feet per Second.	Perpendicular force on one square foot, in Avoirdupois Pounds and Parts.	
1	1 47	005	} Hardly perceptible.
2	2 93	020	
3	4 4	044	
4	5 87	079	} Just perceptible.
5	7 33	123	
10	14 67	492	} Gently pleasant.
15	22	1 107	
20	29 34	1 968	} Pleasant, brisk.
25	36 67	3 075	
30	44 01	4 429	} Very brisk.
35	51 34	6 027	
40	58 68	7 873	} High wind.
45	66 01	9 963	
50	73 35	12 300	} Very high wind.
60	88 02	17 715	
80	117 36	31 490	} Storm or tempest.
100	146 7	49 200	
			} Great storm.
			} Hurricane.
			} Hurricane that tears up trees and carries buildings before it.

It is by these means that the vapors drawn up into

the atmosphere from the sea, are wafted in every direction over the surface of the earth. This distribution goes constantly forward, and the air, however transparent and apparently free from moisture, is indeed always loaded with these invisible vapors. This is evident from the following experiment.

In a summer's day place an empty tumbler upon the table, and it remains hour after hour, dry. Pour now cold water into it until it is half filled, and the moisture, condensed by the cold, will stand in dew drops upon the outside of the glass. The same effect will be produced if any other cold substance is introduced into warm air. There are two ways by which the vapors, thus diffused throughout the air, are made to fall. These we shall describe.

3. CONDENSATION.

(a) *Condensation by Cold.*

Such is the constitution of our atmosphere, that it will receive into itself much more moisture when warm than when cold. The consequence of this is that if warm air, previously loaded with moisture, becomes, from any cause, cold, it can no longer retain that moisture in transparent solution. It consequently assumes again the form of water, — *small, very small drops of water*, — too minute to be seen singly by the naked eye, — but forming altogether a hazy appearance, which we call *fog*, or *mist*, or *cloud*, according to circumstances. There are many ways in which this principle is illustrated.

The breath which proceeds from our lungs is always loaded with moisture. It is nevertheless invisible unless in a cold day, when it appears in the form of a cloud issuing from the mouth. This apparent cloud does not, however, appear to commence precisely at the lips. The warm air must proceed a little distance before it is so mixed with the cold air around as to have the effect produced.

When in cold weather, green wood is burnt for fuel, a cloud of visible vapor issues from the top of the chimney. That is, the vapor, which was *invisible* as it comes from the fire, and as it passes up the flue of the

chimney, *because the air which carried it was warm*, becomes *visible* as soon as it is exposed to the cold air above. It will be observed in this case as in the other, that the condensation does not take place until the vapor has ascended a foot or two above the top of the chimney.

A short time since a large congregation were assembled in a church in Boston at an evening lecture. The heat and moisture produced within the house by the crowd, began to be very great; and when, towards the close of the evening, the door was opened, the cold air rushed in and produced such a condensation of moisture in the air that it was mistaken for smoke and produced a momentary alarm of fire.

(b) *Condensation by the Rarefying of the Air.*

It is observed that generally when from any cause the air becomes rarefied, there is a tendency to condensation of the moisture which it contains. It has been previously shown that when the air becomes rarefied by diminution of the pressure upon it, (see page 114) its temperature is diminished. Now perhaps the condensation of the vapor is owing to this cooling of the atmosphere, though it is on the whole probable that the diminution of density has a direct influence.

A proper consideration of this principle will explain the fact at which so much surprise is sometimes expressed, namely, that *storms move against the wind*. That is, a northeast storm begins in New Orleans and works its way *against the wind* to Boston. This, however, instead of being surprising, is precisely what, with a little reflection, we should have been accustomed to expect. The air over Mexico is rarefied by the sun, and rises. The atmosphere from Louisiana rushes in to supply the vacancy. Virginia then and the states around it must send on a supply to Louisiana. New York must part with a portion of her atmosphere to fill the void in Virginia; and a breeze from New England to New York closes the process. Now it will be evident that the rarefaction which commenced at the southwest gradually will extend towards the northeast, and as it advances, will produce condensation, that is, rain. But the wind at

each particular point through the whole distance will blow in the contrary direction, *i. e.* from the northeast. This accords with well known facts.

These principles in regard to the condensation of the vapors of the atmosphere, will explain a vast variety of facts.

A family sit during a winter's evening by their fireside, and their breath fills the air of the room with moisture. In the night the windows become intensely cold, and the water thus diffused becomes condensed upon the glass in beautiful icy crystals, called, usually, *frost upon the windows*.

In a summer's day the sun, by warming the atmosphere, brings up into it a large supply of vapor. In the evening the grass and the buildings become cool, and the moisture, previously diffused, becomes condensed in drops of dew, which load the herbage to a degree proportioned to the warmth of the preceding day, and to the coolness of the night.

A portion of air having been lying upon the surface of the earth, until it is almost saturated with moisture, at length rises. It expands as it ascends, — can no longer retain its vapor in an invisible form, — and floats, a light fleecy cloud, through the sky.

In a similar case the condensation proceeds farther. Instead of merely forming those minute globules which are too light to fall and too small to be separately visible, the water gathers into visible drops, which form in the air a black and heavy mass, or descend in showers of rain. If they *fall through* a very cold stratum in their descent, they freeze into balls of ice : or *if the stratum of air in which the condensation takes place* is very cold, the vapor shoots into icy crystals, which descend as snow.

In an afternoon in August a river loads the air above it with moisture. The chill of the night cools the whole mass, and in the morning we find lying upon the stream a bank of fog, which the sun's rays cause to *vanish*, but which they do not *remove*. The warmth of the sun enables the air to *hold in transparent solution* the water which was visible before

'Beyond Cape Town,' says Arnott, 'as viewed from

the bay, there is a mountain of great elevation, called, from its extended flat summit, the Table Mountain. In general its rugged steeps are seen rising in a clear sky; but when the southeast wind blows, the whole summit becomes enveloped in a cloud of singular density and beauty. The inhabitants call the phenomenon the spreading of the table-cloth. The cloud does not appear to be at rest on the hill, but to be constantly rolling onward from the southeast: yet, to the surprise of the beholder, it never descends, for the snowy wreaths seen falling over the precipice towards the town below, vanish completely before they reach it, while others are formed to replace them on the other side. The reason of the phenomenon is, that the air constituting the wind from the southeast, having passed over the vast southern ocean, comes charged with as much invisible moisture as its temperature can sustain. In rising up the side of the mountain, it is rising in the atmosphere, and is therefore gradually escaping from a part of the former pressure; and on attaining the summit it has dilated so much, and has consequently become so much colder, that it lets go a part of its moisture. This then appears as the cloud now described: but it no sooner falls over the edge of the mountain, and again descends in the atmosphere, to where it is *pressed*, and *condensed*, and *heated* as before, then it is re-dissolved and disappears: the magnificent apparition thus dwelling only on the mountain top.'

Such are the general principles by which the changes of cloud and rain, sunshine and storm, — and all those meteorological phenomena which occur in the atmosphere are regulated. There are, however, many particular and striking results to which we should be glad to direct the attention of our readers, so far as our limits will permit. The subject, however, which must principally attract our attention must be the effects of electricity.

4. THUNDER AND LIGHTNING.

The various phenomena which are to be classed under the head of electricity, and of which the thunder is one, are very imperfectly understood. Some facts, and the

principles explaining them, have been thoroughly investigated; but others baffle all human efforts.

There is a certain something, called by philosophers *electric fluid*, which is diffused naturally over all bodies. It is in the chair in which I sit,—in the table,—the paper,—my hand,—in a word, in everything. In its natural state it is equally and generally diffused and produces no *sensible* effects. But there are certain causes which *collect* it. When it is thus accumulated in one place or upon one body, it produces very striking results: one of the most remarkable of which is, it tends to dart away into the surrounding objects, *with a bright spark and a noise*. This can be easily imitated on a small scale with the electrical machine; and it is this agent, operating precisely in this way, but with tremendous energy and splendor, which so often terrifies us in the skies.

Among the processes by which the electric fluid is accumulated, and thus prepared to produce these sensible effects, one of the principal is, *the condensation of vapor*, as described on a preceding page. This is shown by a simple electrical experiment which it is not necessary to describe particularly here. But it is considered as established, that whenever the vapor of the atmosphere is condensed, electricity is collected, and tends to dart off into surrounding objects. Whenever a cloud is formed in the sky it probably becomes more or less charged with electricity.

Now it is one remarkable property of this electric fluid, that some substances easily convey it away and others do not. The former are called *Conductors*, the latter *Non-Conductors*. The *metals* and *water* are the conductors: almost all other substances, non-conductors.

Whenever the electric fluid is collected in any place, if there is a conductor, or a chain of conductors, to convey it away, it passes off silently and without any sensible effect. If there are no conductors, it accumulates until it becomes excessive in quantity, and then it darts off through the air or any substances which are in its way,—sometimes with great violence and often doing irreparable injury.

We do not, however, always have thunder and lightning when clouds form in the sky. When a fog rolls in from

the east its vapors lie in contact with the earth and ocean, and the electricity passes off silently as fast as it accumulates. In a long continued storm the clouds cover the whole heavens, and extend over a region of many miles; and they form so slowly that there is opportunity for a gradual escape of the fluid. But when, in a sultry summer afternoon, black masses of cloud rise in the west, — forming very rapidly, and with rounded and well defined boundaries, — the fluid then accumulates faster than it can escape, and after a time it darts to the earth, or from cloud to cloud, producing the terrific effects which we so often see. Splendid and appalling as these results sometimes are, they are imitated precisely, but harmlessly, by the apparatus of the lecturer. The fluid is the same in its movements and in its character, whether it sparkles on the table or thunders in the skies.

When it darts to the earth, its aim is *to pass through the best conductors* it can find on its way. Hence it strikes a tree; that is, it chooses to come down *through the juices of the trunk*; for it will be recollected that water was said to be a conductor. It often seeks a way through the walls and partitions of a house, because it finds there metallic or watery substances which help it forward. But it must be remembered that it strikes these subjects only so far as they *furnish it a passage way to the place for which it is destined*. The common idea that a penknife, or other metallic body, *attracts* the lightning is erroneous. A lightning rod suspended *horizontally* in the air would not attract lightning. It is only when it forms a *connexion* between the place where the electricity is, and that towards which it tends to move.

The following remarkable case will illustrate the principle. The truth of the statements may be relied on. We extract it from the Lon. Phil. Trans.

Remarkable Case of a House Struck by Lightning.

‘ Thomas Olivey, a respectable farmer, had returned from the field, about a quarter before twelve o’clock, and had all his family round him in the kitchen, except his daughter, who was in the hall. There was a pan over the fire in the kitchen chimney, full of boiling water. The farmer was sitting by the fire, and his wife on a

bench before it; their only son, twentythree years of age, was standing at the window, when it lightened much, and the first clap of thunder followed. This was so violent that the back door of the kitchen, which opened to the north, quivered. The farmer called to his son, and desired him not to stand so near the window, lest the lightning should hurt his eyes; on which the young man removed from the window, backwards, into the corner of the room, and sat down. The lightning came from the west-north-west, and falling on the stack of the kitchen chimney, which was about four feet square, and as much in height, of hewn stone, carried it clear off from the house, and threw it into a pool of water twenty feet distant. In the chamber over the kitchen, directly beneath the top of the chimney, there was a little closet boarded in; all the boards were broken to pieces, the timbers of the roof were shattered, as also the bedstead in the chamber. Of the chamber partition, two planks were forced, a large clothes-press thrown down, and the south windows of the chamber floor (excepting the casement) all broken and blown out. From the top of the chimney and chamber floor, it descended into the kitchen below, where the family was. The farmer saw no lightning, nor heard any thunder, after the first clap before mentioned; but was struck senseless by the first flash, and thrown into the middle of the kitchen, and continued senseless for a quarter of an hour. As soon as he came to himself, he asked who struck him; but had not the use of his arms, and felt an aching pain, shooting, as he described it, into his bones.'

A still more striking proof, or rather illustration, of this principle, is furnished by the following case, which occurred in Beverly a few years since, and which is inserted here from the manuscript of an eye-witness.

Thunder Storm at Beverly, Mass.

'As I was going to the school-room, which was to be the scene of my afternoon's labors, I observed a large black cloud rising in the west and covering the whole side of the heavens with its black shade. The school hour arrived just as it began to rain,

and by the time that the boys were engaged in their work, the tempest came on with such violence as to put a stop to almost every proceeding. The wind blew and the rain poured down so as to make a complete turmoil without, and the thunder, which seemed to hover directly over our heads, and to be bursting all around us, rendered conversation almost perfectly inaudible. The lightning had not the appearance of a flash diffused through the air, but it glittered on the seats with a brightness which almost blinded me, and immediately upon it came the peal, so loud and terrifying, that almost every face in the room was distorted as if from a bodily pain. During this time, at the intervals between the flashes, the room was so completely darkened as to render it impossible to see to write even the large hand copies which were before the scholars. I have heard loud thunder before, but never seemed to be so completely in the midst of it. It appeared to keep up its unceasing rattling all around us, without intermission or abatement.

‘It began however soon to look less dark, — the peals followed each other less rapidly, and were more distant from the flashes to which they belonged, — and as they passed off towards the east, they gradually changed their sharp and broken rattling, for the prolonged rumbling sound of distant thunder. The wind died away; — the rain only sprinkled upon the windows; — a broad-bright zone was rising in the west; — the sun soon broke forth in it, and all was over. The cloud lay for some time in the east, discharging its bolts into the water, and then left us not a little relieved by its departure.

‘I was soon informed that the lightning had struck in several places; to one house particularly, it did much injury, and destroyed one life. The next morning I went to visit the house, and found it in the situation which I will attempt to describe.

‘The lightning had first struck the chimney; in the garret there was hanging a saw from one of the rafters at the distance of a few feet from the chimney; the saw reached very near to the floor. Nearly under that part of the floor over which the saw was suspended, there was a closet. Now it happened that the mistress of the

house stood a few moments at the closet with her head *exactly under the extremity of the saw*; though the garret floor was between them. This was in the second story; on the lower story, there was nearly under the place where the woman was standing, some metallic substances, particularly a large pair of tongs, which stood up by the fire-place. There was thus, it will be observed, a continued chain of conducting substances, extending from the top of the house to the ground, and the lightning pursued precisely the track prepared for it. It descended by the chimney, ran down the roof, tearing up the shingles, until it came over the saw; it passed down the saw easily, and without injury, as the steel was a good conductor. It then perforated the floor, making several small holes, like those produced by a gimlet. It passed through the body of the woman whom it instantly deprived of life, and thence found its way through the metallic substances in the kitchen to the ground. Another lady sitting at the window of the room, in which the woman was killed was not injured in the slightest degree.'

Such is the account of this very clear and striking instance of the unerring certainty, with which the lightning selects its path *through the best conductors*, which it finds in its way. A saw *lying horizontally*, would have had very little influence, unless it should even in that position, form part of a connected series of conductors to the earth. The reason why one person was safe in the immediate vicinity of such danger was, that she was out of the series of conductors.

We have from these and other similar cases, a very simple direction, which will enable us to avoid danger, so far as it is possible to avoid it, and that is, take such a position *that the body shall not be one of a series of substances likely to conduct the fluid*. More particular rules cannot be given, for the circumstances vary so much, that they would be of very limited application; each individual keeping the general principle in view, must judge. The middle of a room, or lying horizontally upon a bed, are for obvious reasons, the safe position.

It may here be observed that the flash and report, or which is the same thing, the lightning and thunder are

precisely at the same moment, and one never takes place without the other. It is true that we often see the flash some time before we hear the sound, and so do we often see the smoke of a distant gun, long before we hear its report. The reason is not that they are in reality separated, but because light travels faster, and reaches us sooner than sound; and as the apparent separation is proportional to the distance, the latter may be calculated pretty accurately by observing the former. It is true also that we sometimes see a cloud in the evening which emits frequent flashes in apparent silence. This is not because it is a different species of lightning; — but because in the darkness of the hour, the light may be seen at so great a distance, that its thunder is not heard. On the other hand, when the cloud rises in the day-time, we hear the thunder first, because in the glare of the sun, the flash must be vivid before it can be seen. The phenomena are, without doubt, in all cases the same; and when the cloud is near, the peal follows instantaneously upon the flash; at a less or greater distance it is in a small or great degree separated from it. When the cloud approaches us in the dark, as might have been expected, we see the light before we hear the sound; and when it comes in bright daylight, the peal is heard before the flash is visible.

We have thus described as fully and to as great an extent as our limits will permit, the principles by which the changes of the weather are regulated. We must not forget the great object of the whole, which is to take up from the ocean the waters which rivers and streams are continually bearing to its bosom, and distributing them again over the earth to refresh and to fertilize. In considering this subject we know not which most to admire, the skill which contrived this system, or the omnipotent control, which confines these elements of agitation within such bounds, that they seldom encroach upon human life, or even disturb the peaceful and happy employments of society.

SCIENTIFIC TRACTS.

NUMBER X.

THE ART OF BUILDING.

SIR CHRISTOPHER WREN has remarked, that the art of building has its political, as well as civil use; and national monuments being the ornament of a country, it establishes a nation, increases population and commerce, makes people love their country, which is the origin of all great actions in a commonwealth.

This is the testimony, not only of one of the best architects that ever lived, but of a very wise and good man, on the importance and utility of architecture; we therefore consider the art of constructing beautiful and permanent edifices one of the most important occupations of man. If architecture is so important, every exertion should be made to advance the proper understanding of all its parts; every auxiliary should be thoroughly taught to perfect this noble art.

The advancement of our country in the arts of life and civilization has been most rapid and successful, as is most clearly shown, by the improvements made in the art of building. Within twenty years a progressive and judicious reform has been made in the architectural appearance of our cities, towns and villages; there is an improved taste manifest, not only in the construction of our national monuments and public buildings, but also in our private dwellings. A very great improvement has also been made in the durability of our buildings, substituting for wood the imperishable materials of stone and brick; and these improvements are in no small degree

owing to the increased skill of our masons, not only in practice, but in the theory of their art.

Notwithstanding the improved taste and skill, manifest in the art of building, there is a want of science among our masons, when compared with those of England and France, where the blind routine of practice is guided by the light of science; where as much learning is considered necessary to construct a church or bridge, as to plead a cause in a court of justice. Our remarks will apply equally as well to most of our mechanic arts, as to building—in all of which, science is the only thing required to render them equal to those of any country.

The want of science among our mechanics we attribute entirely to the want of proper elementary instruction, and it is with a view to remedy this defect in one trade, that the following pages have been prepared—not for the master builder only, but for the great mass of our countrymen; we wish to spread the scientific principles of the arts and trades before the *whole people*. We wish that every mechanic in our country, may not only know the science of his own profession, but also that of every other with which his own is in any way connected, believing that this knowledge would not only add greatly to his pecuniary gains, but vastly increase his means of happiness.

In a short way we propose to describe the principal materials employed by the mason in the construction of edifices, with a brief account of their application; to which we have added a concise description of the principal manual operations of the mason's trade.

MATERIALS.

Stone.—This is the most durable material of which buildings can be constructed. There are various kinds of stone which are used for building in the United States, such as limestone, granite, gneiss, sienite, and sandstone. Limestone is used extensively in New York, Pennsylvania, and some other states. Granite is used abundantly in the New England states, where it is found in great abundance. Sienite is used extensively in and near Boston. Gneiss is principally used for cellar and

foundation walls. Sandstone is used for building in almost every part of the country.

Limestone is of several kinds — granular limestone (*Marble*) and compact limestone (*common limestone*) are the two principal varieties. All limestone is essentially composed of carbonic acid, (*dead or fixed air*) and quick lime; it is of various colors — white, gray and veined. This stone may be distinguished from all other building stone, by putting a small piece into diluted sulphuric acid, when it will effervesce or bubble like soda water, which is caused by the acid combining with the lime, and thereby setting the carbonic acid gas free. It is about $2\frac{3}{4}$ times heavier than water.

Among all the kinds of limestone used in building, marble holds the first place, both as respects durability and beauty. Marbles are principally used for interior decorations. The principal kinds are the following.

1. White marble, which is used for statuary and interior decorations; the coarser kinds are often used for exterior walls; the City Hall in New York, and the State Prison at Sing-Sing, in New York, are examples of this species. This kind of marble is found in Vermont, (*Middlebury*) Rhode Island, (*Smithfield*) and Massachusetts, as well as many other places.

2. Colored marble is of many shades, and is used principally for interior decorations. It is found in abundance in most parts of the country.

3. Breccia marble is that kind of marble which is apparently made up of different sized fragments imbedded in different colored cements, the fragments are of all sizes and shapes; and when polished present a very beautiful appearance. The most beautiful variety in this country is found on the Potomac river, fifty or sixty miles above Washington city. It is used for interior decorations. The shafts of the columns in the Representatives' Hall, in the Capitol, are formed of this marble; they are nineteen feet nine inches in height, and two feet in diameter at the base. There are many other varieties of marble, but they are seldom used by the mason.

Granite. — This is one of the best materials for the construction of buildings, and is composed of three substances, *feldspar*, *quartz*, and *mica*; it is gra-

nular, the grains varying from the size of a pin's head to that of a nut or even larger.

The color of granite depends upon the feldspar, which is white, gray, yellow, green, &c ; the predominant color is gray ; its beauty for building depends upon the intimate mixture of the white feldspar and black mica. Granite is not generally acted upon by fire or water, nor does the frosts of our winters affect it ; it is about two and a half times heavier than water.

Granite is found extensively distributed over the whole surface of the earth. It forms the principal part of the highest mountains, and is found in low places, in beds, or what are called *ledges* ; single blocks of granite are found resting upon loose earth.

Beautiful varieties of granite for building are found in Maine, New Hampshire and Massachusetts.

Granite is used by the mason for the construction of whole edifices, and for window and door stools and caps, also for ashlar ; in some situations it is used undressed, for foundations, cellar-walls, &c.

Sienite resembles granite in its external characters, but differs from it in being essentially composed of *feldspar* and *hornblende* ; sometimes it contains quartz and mica. Feldspar is the principal ingredient in sienite. This stone is much less abundant than any other stone which is used for building ; it is found in the vicinity of Boston, where it is extensively used. The Stone Chapel and Tremont House in Boston, the State Prison (old) in Charlestown are built with sienite. This stone received its name from *Siena*, a city in Egypt, whence the Romans obtained it for building and statuary.

Gneiss resembles granite in its appearance, and is of the same composition, but differs from it in always being more or less slaty, and when viewed in the mass, appears to be formed of layers of different colors. Gneiss is a hard rock, and answers very well for cellar and foundation walls.

Sandstone (*Grés of the French, Freestone*,) is composed of grains of quartz united together by a cement, which is variable in quantity and quality ; it may be limey, clayey, or even silicious. The texture of some sandstones is loose and porous, while some are hard and

compact. The most common kinds for building are red, white and gray. In New England the red sandstone is extensively used by the mason for jambs, hearths, door and window caps; there are, however, some kinds of sandstone which are easily affected by the frost, and of course should not be used in our climate. We may observe several specimens of this in Boston, in which the frost has caused them to crumble to pieces.

These stones are extracted from quarries or from single beds. In quarrying limestone gunpowder is necessary in detaching the stone at first, after which it is split with wedges. Granite is quarried by means of wedges only when taken from single blocks, gunpowder is used when in large masses. Sandstone is generally found in layers, and it is quarried with the pick, wedge and lever. Gneiss, generally, only requires the wedges and hammer.

BRICKS.

Brick is the next most durable material to stone for building. Bricks are made of clay mixed with a certain portion of sand; the quality of the brick depends mainly upon the proportions of these ingredients; if there is too much clay, they shrink greatly in burning, and if too much sand, the bricks are brittle and heavy. The proper tempering of the raw material has another great effect upon the quality, which is most effectually done by means of a *pug-mill* instead of the rude contrivance of our New England brickmakers. This mill consists of a hollow, upright cone, the interior being set with knives arranged in a spiral form; in this cone an upright shaft is placed, armed in the same manner with knives, having a pivot at the bottom on which it revolves. The clay being put in at the top and a horse attached to the shaft, the knives cut, separate, and most admirably prepare it for the moulder's bench.

Bricks are burned in kilns in this country, which, previous to the fire being applied, are covered with a coat of clay and sand; this being a bad conductor of heat keeps it in. A kiln forty bricks long, thirtyseven wide and thirty high, will require about sixty cords of pine wood, or about half a cord to a thousand. The heat in burning

bricks should be applied gradually, till it attains its greatest height, because a sudden application would cause the bricks to break as they are bad conductors of heat.

Bricks are of several kinds, as marls, stocks, and place. The finest marls are called *firsts*, and are used for arches; the next best are called *seconds*, and are used for fronts. Stocks are similar to seconds, and are used for the same purposes. Place-bricks, samel or salmon, are such as were on the outside of the kiln, and are not thoroughly burned, consequently are pale and soft. There are also burrs or clinkers, which are such as were too violently burned.

There is another division of bricks founded upon a difference in the manufacture, viz. pressed and unpressed, or common bricks.

Pressed bricks are such as after being partially dried, are subjected to mechanical pressure, and then are burned, which increases their density and beauty.

The use of bricks in constructing buildings is of the highest antiquity. The first bricks made by man were rude masses of clay, hardened in the sun; afterwards, they were regularly shaped. The tower of Babel or Belus, was built of sun-dried bricks. The ruins of Babylon are of the same material. The ruins of a pyramid near Grand Cairo in Egypt, erected by Asychis, is of unburnt bricks. The ancient Greeks and Romans used the same material in their edifices—the walls of the temple of Jupiter and Hercules—the palace of Cræsus at Sardis, &c. Augustus boasted that he found Rome of brick and left it of marble. The Roman bricks were square and triangular, the last being just half of a square one cut, diagonally, and formed the outsides of the walls, the square ones being laid diagonally across the thickness of the wall.

Mortar. — Mortar is made of quicklime and sand, each of which we shall describe.

Lime is the soul of masonry, and is the principal substance used for joining stones and bricks together in the construction of masonry.

Quicklime is obtained by the calcination of limestone, the heat driving off the water and carbonic acid. Limestone is generally contaminated with alumina

(*clay*), magnesia, and the oxides of iron (*iron rust &c.*, sometimes with sulphate of lime (*lime and oil of vitriol called gypsum, or plaster of Paris*) when the limestone is hard enough to scratch glass it contains quartz, when of a brown or red color it contains oxide of iron, when it effervesces slowly, producing a milky appearance it contains magnesia; and when black with a bad smell it contains coaly substances. Magnesia and clayey substances impair the quality of the quicklime by preventing its *setting well*.

The hardest limestones make the best quicklime.

There are two kinds of quicklime used by masons, common lime and hydraulic or water lime; the latter differs from the former in containing iron and manganese. The best common lime comes from Thomastown, Me. A good hydraulic lime (*cement*) manufactured in New York, was used for constructing the locks of the Grand Canal.

Lime is nature's universal cement, and is employed frequently in an immense number of her combinations. Besides the great masses of limestone on mountains as well as in plains, besides the great variety of compound stony substances, widely diversified, of which it forms an essential part, it is found in vegetables. The bones and shells of all animals are formed of the same substance united with certain acids.

Sand is the next important ingredient of mortar. On the quality of this, essentially depends the quality of the mortar, and if it contains any clay or mud, or is brought from the shores of salt waters, it is unfit for mortar until it is washed, because the clay or salt will prevent its setting, these substances having a greater affinity for water than for carbonic acid. The sharper and coarser the grain of the sand, the better the mortar and the less lime is required, which of course diminishes the price; it should be a general rule to use no more lime than what is just necessary to cover every particle of the sand.

The celebrated Rondelet, a French engineer, and Mr Smeaton, the builder of the Eddystone light-house, made numerous experiments on mortar. The following are some of their conclusions.

1. Pit sand, mixed with lime, makes a better mortar than river sand.

2. Pit sand, fresh dug, makes a better mortar than that made of the same sand dried in the sun.

3. A mixture of lime and old mortar as cement, forms a better mortar than the best sand and lime.

4. The darkest colored sand makes the best mortar.

It would be vain for us to attempt giving any rules as to the proper proportions of sand and lime to form a good mortar, owing to the various qualities of the lime; if it is perfectly pure and caustic, fifty parts of sand to one of lime would be the proper proportions; but the most common proportions in this country are two parts of sand to one of lime. In this country our masons err greatly in using too little sand, and in not mixing what they do use thoroughly and intimately with the lime. The quality of the mortar depends essentially upon the slacking of the lime; it is of the utmost importance that every particle of the lime be thoroughly slacked; if any parts of it are mixed up before it is slacked, the water continuing to act upon it, will cause it to expand, and in plastering will cause blisters. But a small quantity of lime should be slacked at a time unless it is protected from the air, as it will absorb carbonic acid gas from the air, which injures the mortar.

Cement Puzzolanas, Tarras. — For the construction of masonry in water, a peculiar kind of mortar is necessary — common mortar will not harden in water. For lining reservoirs or tanks, common mortar may be used, if they are suffered to dry and harden before the water is let in. For hydraulic works, cement, puzzolanas and tarras are mixed with lime, which forms a mortar that sets immediately in water. There are various kinds of cement. The Roman cement which comes from England, is composed principally of a calcined marl. The Dutch cement is tarras and lime, one of the former to two of the latter.

Puzzolana is the production of volcanoes, and is composed principally of marl, and is found in Italy. Greenstone calcined and powdered, mixed with lime and sand, formed the mortar with which the famous Eddystone lighthouse was constructed by Smeaton.

Grout and Grubbstone mortar. — Grout is nothing more

than thin mortar, and is generally *poured* upon masonry to fill up all the interstices.

Grubbstone mortar is made of water, lime, sand, and small rough fragments of stone; it is used for foundations and other works in water; it is sometimes employed for filling up between the two faces of a wall, to render it water tight.

MASONRY.

Having detailed in a brief manner the different materials used by the masons, we now proceed to show their application.

Masonry is the art of forming cut stone, rubble or brick into masses by means of mortar or plaster; of course, there are several kinds of masonry — the two principal however, are Regular and Irregular.

Regular masonry is formed of stones or bricks of a regular form. The object of all kinds of masonry is to form with a number of pieces of stone or brick, one mass which shall have the solidity of a single block.

The ancients employed stones of a much greater size than are used at the present time. In the ruins of Persepolis there are single blocks, weighing over 500 tons. In the great temple of Balbec, there are single blocks weighing 1000 tons.

In this country cut stones are called ashlar, of which most of our stone edifices are built, the stones being of various length, but should always be of the same length for the same building. Where the face stones are not so thick as the wall, it is customary to fill in the back with rough materials, in which case the backs of the face stone, or ashlar, should not be parallel to the front face, but inclined; and every stone should have its back inclined in the same direction, which will give a certain lap to each course. In all kinds of face stone work, every course should have a number of thorough stones in it, that is, stones which go through the wall; these are necessary to the stability of the work.

Brick masonry is that which is most common in our country. In building brick work in dry weather the best of mortar is necessary, and the bricks should be dipped in water as they are laid, to cause them to adhere;

because the brick being porous and dry, will absorb so much of the water from the mortar as to prevent its sticking.

In building a wall of any kind, not more than four or five feet of any part should be built at a time, because as we have stated in our *Tract on Heat*, the mortar shrinks on becoming solid; and if one part of the wall shrinks before the other it will cause a rupture.

There are two kinds of bonds used by masons. English and Flemish. The English bond consists of a course of bricks laid lengthwise, then another underwise to the face of the wall. There is but one objection to this bond, which is the difficulty in breaking joints, which requires that a brick should be broken at every course. The Flemish method consists in placing a header and stretcher alternately. This is deemed much neater than the former; but in the execution it has some inconveniences and is not thought to be so firm as the English.

The masons of Boston adopt a different bond, they lay five or seven courses of stretchers and then one of headers. This, however, is thought by some, must yield to the English and Flemish, not only in beauty and practice, but greatly in strength, because there is not a sufficient bond between the two faces of the wall.

In laying all kinds of stone masonry, it is of the utmost importance that each stone should lay on its natural bed, otherwise the joints will flush, and frequently the stone will break; a glaring instance of this may be seen in the front of St Paul's church in Boston, where the stones are ruptured, in consequence of this very fault. It is also of the utmost importance that each bed of the material should be perfectly level and smooth, otherwise the joints will flush out and ruptures will be produced.

Rubble stone masonry is such as is made of unhewn stone; it may be laid in courses, or in an irregular manner. In coursed rubble, the stones are all gauged to the same height, but in uncoursed rubble the stones are laid promiscuously in the wall, only having the sharp corners knocked off.

The strength and durability of all masonry when it has been laid in a proper manner, with good lime, depends entirely upon the force with which the mortar ad-

heres to the stones or bricks, as well as the adhesion of its own particles. These forces are greatly augmented by age.

The following table shows the force with which stone and brick adhere together, when joined by good mortar made of nine parts of sand and one of good lime.

Two pieces of Maine granite, hewn,	105	pounds.
The same not hewn, - - -	162	"
Red sandstone, hewn, - - -	159	"
The same not hewn, - - -	166	"
Sienite, (Quincy) hewn, - - -	101	"
The same not hewn, - - -	147	"
Boston unpressed brick, - - -	172	"
ditto pressed. - - -	167	"

These had all been united nine months, and placed in a dry situation.

The following appears to be the principle on which mortar acts as a cement in joining masonry. It is well known that when quicklime and water are mixed together, the lime swells and falls to pieces, and is soon reduced to a fine powder, and so much heat is produced as to convert a part of the water into steam. If the lime be weighed after being slacked, it will be found to have increased in weight, which is owing to a part of the water having combined with the lime and become solid; of course, the water has parted with that portion of its heat which caused its fluidity; hence, the great heat produced in slacking lime — for if two parts of powdered quicklime and one part of powdered ice (both at 32° of the thermometer) be mixed together, they instantly combine and their temperature is 212° . Here the increase of heat comes from the ice. When large quantities of lime are slacked, heat and light are produced in large quantities — hence the reason vessels and buildings filled with lime are often set on fire by the water getting to it. This combination of lime and water, is called a *hydrate of lime*.

When the hydrate of lime is forming, if the black oxide of iron, or the scales thrown from it when hammered by the smith, be mixed with burnt clay or sand, the mixture becomes harder than the lime would alone, which is owing to a certain degree of chemical attraction between the hydrate of lime and these substances.

If the oxides of iron or burnt clay are used, the mortar has the property of not being acted upon by water, and thus forms a *cement*.

Most persons must have observed that buildings formed of masonry, require to have their joints pointed over or refilled, the old mortar having become *rotten*; this is owing to the action of moisture and the carbonic acid gas which is in the air, the gas having united to the lime and formed limestone, and thus destroying the attraction which the hydrate of lime had for the sand, which causes the mortar to crumble and fall to pieces.

From the above principles we may explain the cause why lime exposed to the air, becomes slacked and finally loses its properties—the moisture of the atmosphere combines with the lime and slacks it, or forms a hydrate; the carbonic acid gas from the same source, then, combines with the slacked lime or hydrate, and forms a carbonate of lime. This may again be made quicklime by heating it violently, which expels the water and gas.

FOUNDATIONS.

Having described the materials used by the mason, and explained the principles of their action on each other, we now proceed to describe some of his operations in erecting a building or other work.

The laying of the foundation is the first operation in constructing a building, and is the most important part of the whole work; without a firm foundation it is in vain for the mason to attempt to produce a permanent building. Almost every city in our country can show the pernicious effects of masonry constructed without a due regard to the foundation. Boston can show some lamentable instances, where rents and settlements are to be seen from the cellar to the ridgepole.

Wherever it is intended to erect masonry, the ground should be examined with an iron bar, or a well diggers' auger, which will not only show the composition of the earth, but the depth at which solid ground is found, which will determine whether the earth can be excavated to the solid bottom or not.

When the soil is loose to any great depth, the foundation may be well established by turning inverted arches under each aperture and opening, as the doors and windows; by this means the foundation is rendered perfectly safe and solid, because the sinking of the piers will carry the arches with them, and thus push the ground under them, which presses it against the under sides of the arches; the arches of course, will not give, if properly constructed; where this expedient is not used, those parts of the wall which are under the apertures, or doors and windows, not being so heavy as the solid parts of the wall, will be left behind when the solid parts settle, because the resistance of the soil will keep them up, causing fractures in the wall, and frequently in the window caps and sills.

In so essential part of a foundation as the arch, great care should be paid to its curve, and the curve, called a parabola, should be used in preference to any other; next to this the semi-circle.

The most common method in this country is to establish foundations in soft earth, upon piles; these are driven into the ground, and the foundation stones laid upon them. In using piles, great care is requisite that they be driven down to the firm bottom; it sometimes happens that the piles stop before they have reached the solid ground, and if the masonry is placed upon them in that state, the walls will certainly be ruptured — therefore, such piles should be left a short time at rest, and then apply the pile engine and it will drive them down to the firm bottom; this stoppage is produced by the friction of the pile and the resistance of earth. An important instance of the fracture of walls established upon piles occurred in Boston a few years since on Central wharf.

It sometimes occurs that a foundation is required to be constructed on inclined ground, in which case the walls should rise in a series of level steps. This will endure a level and firm bed for the building walls, and prevent their sliding, which they would be apt to do in moist situations, thereby causing serious fractures if not the entire destruction of the building.

Where a foundation is laid upon piles, it is important that they are not overloaded, which will cause their rupture and the overthrow of the building. In order to determine the weight which each pile should support without bending, we must know the total weight of the mass of masonry which is to be placed upon them, together with the dimensions of the piles, from this we may determine the number of piles. The total weight of the building may be ascertained by calculating the solid contents of the walls from the bottom of the foundation to the top of the building, to which the weight of the wood-work &c, must be added, and the doors, windows and other openings must be subtracted. Having found the cubic contents of the masonry, we may find their weight by knowing the weight of one cubic foot of the stone or brick, or what is the same thing, the *specific gravity*. Specific gravity may be defined as the relative weight of any body when compared with some other of which we know the weight, one cubic foot of pure rain water weighs just 1000 avoirdupois ounces, and this is the substance with which we compare the weight of solid bodies. Example. How much will one cubic foot of Chelmsford granite weigh more than one cubic foot of water? The determination of this is determining the specific gravity of Chelmsford granite. If we could cut out a block of this stone, exactly one foot on each side, we could easily weigh it, but this cannot be done for practical purposes, and if it could, we may arrive at the same conclusion much easier.

It is evident, that if we drop a piece of stone or brick into a tumbler or other vessel filled with rain water, the stone will displace a part of the water just equal in bulk to itself, and if the stone be weighed in the water it will be found to have lost just as much in weight as the water displaced will weigh, therefore we have the weight of the piece of stone and the weight of an equal bulk of water, which is the *specific gravity*. Suppose the stone weighed $3\frac{1}{2}$ pounds out of water, and one pound in the water, here the bulk of water equal to that of the stone weighs $2\frac{1}{2}$ pounds, and the specific gravity in the relation or proportion between $2\frac{1}{2}$ and $3\frac{1}{2}$ which is $1\frac{1}{2}$ or 1.4. In this

way we may determine the specific gravity of any body which is heavier than water.

Knowing the specific gravity of any body we know the weight of one cubic foot of it. As a cubic foot of water is just 1000 ounces, if we multiply this number by the specific gravity, we have the weight in ounces and from thence in pounds, &c.

The following table of specific gravities of several bodies will answer for all practical purposes, instead of calculating them as above.

Iron, wrought, -	7645	Clay, - - -	2160
Iron, cast, - -	7425	Brick (<i>unpressed</i>)	1980
Granite, Maine, -	2731	Brick (<i>pressed</i>) -	2050
Do, Chelmsford,	2910	Earth, common about	1989
Sienite, Quincy, -	3000	Sand, - - -	1520
Limestone, - -	2635	Sea water, - -	1030
Marble, - - -	2840	Common water, -	1000
Sandstone (<i>Freestone</i>)	2435	Slate, - - -	2541

Note. The specific gravity of water is here called 1000, which is just its weight in ounces, therefore the numbers in this table express the weight of one cubic foot of each substance in ounces.

From the above principles we may find the solid contents of any irregular body, provided we know the weight and specific gravity. The above numbers in the table are the weights of one cubic foot or 1728 cubic inches in ounces; therefore if we find how many times the number of ounces in one cubic foot is contained in any given weight, we find how many cubic feet there are in that given weight, the remainder, if any, reduced to inches and divided will give the cubic inches.

Example. Required the solid contents of an irregular block of sienite which weighs $231\frac{1}{4}$.

Answer, $1\frac{1}{2}$ cubic feet.

The reverse of the above rule we have explained, that is, to find the weight, knowing the dimensions and specific gravity, multiply the solid contents in feet by the specific gravity, and it will give the weight in ounces.

Having determined the weight to be supported by the piles, we may determine their number and size. It has been found from experiments, that each pile should not

be calculated to sustain more than 50,000 pounds when 9 inches in diameter. The piles cannot be placed nearer together than a certain distance, if they are the ground will be so much compressed as to render the driving of them very difficult, if not impossible; the nearest distance at which they can be placed has been determined by numerous experiments to be $2\frac{1}{2}$ feet from centre to centre.

It is well known that a piece of wood will resist a pressure on its end, acting in the direction of the fibres, in exact proportion to its number of fibres, or its size — but its length has some influence upon its resistance. It has been found that as pressure is increased, the length should decrease according to its square; that is, if a stick of timber or pile be 25 feet long and just support 1000 pounds, if the pressure be increased to 2000 pounds the pile must be decreased, not to $12\frac{1}{2}$ feet, but to 5 feet to be just as strong.

Our conclusions then, from this elementary detail of principles, are as follows; piles should never be placed nearer together than $2\frac{1}{2}$ feet, and should never be calculated to support more than 50,000 pounds.

The construction of stone arches is the most difficult and useful part of the practical mason's trade. The methods now in use for finding the patterns of the stones for arches of various descriptions, are not only laborious but exceedingly difficult and perplexing. A knowledge of descriptive geometry as applied to finding these patterns, would be an important acquisition to the masons; by means of this science, what requires the labor of weeks in the old way, may be performed in a few hours. Our limits will nor permit us to explain this highly important science, as it would require the space of two or three tracts.

Stone Houses.—The beauty of a stone building depends mainly upon the kinds and finish of the stone, and where the stones are handsomely cut and in proper shape, it leaves scarcely anything to be desired. Houses and other buildings are constructed in an economical manner, particularly in the country, of rough stone of any kind, to which great beauty may be given by covering them on the outside with plaster or cement. For this kind of construction the following principles should be adhered

to. Where it is intended to construct a house of stone and then cover it with cement, the face of the walls should be left as rough as possible; therefore, small stones will answer better than large ones; the joints on the outside should be left as open as possible, and no small stones or mortar should be put in between them. After the walls are completed the cement may then be applied.

The cement or mortar should be made of pure lime, and if it is slacked with water in which lime has been dissolved, so much the better; the sand should be pure and coarse, from the size of a pea to the head of a large pin, and mixed with a suitable quantity of lime and hair. This mortar should be put on, and floated over all at one operation, and should be done as quick as possible.

Only one coat should be applied, as another would not stick, if applied, the first frost would take it off. The plaster may afterwards be beautified by a lime wash made of milk instead of water, of any required color; the cheesy part of the milk forms with the lime a kind of varnish without gloss, which is not acted upon by water and air.

A cement put on as here directed is *permanent* and will stand fifteen or twenty years without repair.

Stone houses are not only the most durable when properly built, but do not yield in beauty to those of any other material, and where stones are plenty, they are the most economical. Stone or brick houses should never be plastered upon the stone, but upon lathes fixed to *furrings*, (see article, *plastering*).

Chimneys. — The building of chimneys has always been considered a very important part of the mason's trade. There are a few principles which we conceive may be of advantage to the practical man in this part of building. Count Rumford, whose experiments on the economy of fuel and heat are numerous and interesting, says, that the back of the chimney should never exceed two thirds of the opening in front, and that the jambs or sides should incline to the back in an angle of 135 degrees, or what is the same thing, three mitres: because this *flare* or opening, sends out more heat than any other; which may be easily explained by those who understand the

elements of Plane Geometry, in the following manner. Heat moves in straight lines, perpendicular to the hot body or fire, therefore, the heat from the ends of the fire will strike the jambs at the same angle, on one side, as the jambs and back make, on the other side; the angle will be just 45 degrees, or a mitre. This is the angle with which a ray of heat strikes, and as it is a law of heat that it is reflected, or will fly off, at the same angle with which it strikes, that will be 45 degrees more; and of course, the angle between the striking ray and the reflected ray will be 90 degrees, or two mitres; and as no other angle but 135 degrees will give these proportions, this must be the true *flare* or angle. A less angle, however, may be used according to the size of the room and the nature of the fire, whether for coal or wood; for a small room and when coal is to be used, a less angle will answer. The back of the chimney should be brought within four or five inches of the mantel bar, or breast of the fire-place, for the following reasons.

It is known that the smoke ascends in a chimney in consequence of the air therein being rarefied or warmed, which renders it lighter, and it therefore ascends carrying the smoke with it; this warm air is replaced by the colder air of the room; by this means a current is produced, and the smaller the opening (to a certain point) the greater the draught or current. For the same reason the flue should be placed as directly over the fire-place as possible, and should be straight and smooth the whole extent; the flue should be about 14 inches wide. The most common material for fire-places is brick and jambs of sandstone, marble or soap-stone (*steatite*) is now used extensively; this is far preferable to sandstone or dark colored marbles, as it is of a light color, takes a tolerable polish, and becomes hard and durable by exposure to heat. Light colored, polished jambs, are the best, because they absorb less heat and reflect more than dark colored and rough substances.

It sometimes happens that chimneys constructed in the above manner, will, notwithstanding, smoke, particularly if the top should be overtopped by some other building, as in that case eddies of air are produced which will drive the smoke down chimney; in which case the

chimney must be raised up to the overtopping object, or covered with a *pot* or cap as recommended by Mr Tredgold of England.

His method consists in placing in the top of the chimney a cap of brick or iron, formed in the following manner: the top opening of the chimney is constructed in size, according to the following rule. Divide seventeen times the width of the grate or fire-place in inches, by the square root of the height of the chimney in feet, the quotient is the area of the opening at the top in square inches. It should be understood however, that this opening should never be less than 6 inches in diameter, and seldom more than $6\frac{1}{2}$; — the inside of the cap or hood should be rounded off, and made as smooth as possible, so that the smoke may meet no obstacle. This plan is very general in Boston, and gives a neat finish to the top of the chimney, as well as prevents it from smoking.

Measurement of Masonry.—Although it is not customary at the present day for masons to work by measure, yet it may be useful to know the rules for measuring stone and brick-work. We accordingly give a few of them.

Stone work is generally measured by the cubic foot or perch, and almost every city has its particular rules as to what parts of the work shall be measured in taking the dimensions, therefore, no general rule can be given for stone work. Brick work is either estimated by the rod or by the thousand inches; therefore, a rod of brick work is $16\frac{1}{2}$ feet square and $1\frac{1}{2}$ bricks thick or $13\frac{1}{2}$ inches; therefore, a rod of brick work is 306 cubic feet, while a perch or rod of stone work in some places is only $31\frac{1}{2}$ solid feet; therefore, for brick work the rule is, multiply the area of the wall by the number of *half bricks* in thickness, and divide by 816 and the quotient is rods, and the remainder, if any, feet.

A rod of brick work laid in mortar will require 4500 bricks, a cubic yard 460. For paving, a yard of work, 82 paving bricks, or 38 bricks laid flat, are required.

Masons and others are frequently called upon to estimate the quantity of materials necessary to construct any given work; this may be easily done by the common rules

of arithmetic. For a stone building it must be done in detail, by finding the number of stones of each dimension and finish, which will be required.

For brick work it is different; we have only to find the superficial contents of the building, and then by estimating 4500 bricks to each square rod, when the wall is $1\frac{1}{2}$ bricks thick, we have the total number required; this is the number with a proper allowance for waste, &c. To facilitate these calculations, the following table is here introduced.

Area of the face of the wall.	The number of bricks thick and the quantity required.				
	1-2 brick.	1 brick.	1 1-2 brick.	2 bricks.	2 1-2 bricks.
1	5	11	16	22	27
2	11	22	33	44	55
3	16	33	49	66	82
4	22	44	66	88	110
5	27	55	82	110	137
6	33	66	99	132	165
7	38	77	115	154	193
8	44	88	132	176	220
9	49	99	148	198	218
10	55	110	165	220	275
20	110	220	330	441	551
30	165	330	496	661	827
40	220	441	661	882	1102
50	275	551	827	1102	1378
60	330	661	992	1323	1655
70	386	772	1158	1544	1930
80	441	882	1323	1764	2205
90	496	992	1488	1985	2480
100	551	1102	1654	2205	2757
200	1102	2205	3308	4411	5514
300	1654	3308	4963	6617	8272
400	2205	4411	6617	8823	11 029
500	2757	5514	8272	11 029	13 786
600	3308	6617	9926	13 235	16 554
700	3860	7720	11 580	15 441	19 301
800	4411	8823	13 235	17 647	22 058
900	4963	9926	14 889	19 852	24 816
1000	5514	11 029	16 544	22 058	27 573
2000	11 029	22 058	33 088	44 117	55 147
3000	16 544	33 088	49 632	66 176	82 720
4000	22 058	44 117	66 176	88 235	110 294
5000	27 573	55 147	82 720	110 294	137 867
6000	33 088	66 176	99 264	132 352	165 441
7000	38 602	77 205	115 808	154 411	193 014
8000	44 117	88 235	132 352	176 470	220 588
9000	49 632	99 264	148 896	198 529	248 161
10 000	55 147	110 294	165 441	220 588	275 735

By this table, the number of bricks required to construct any given work may be found immediately, by knowing the superficial contents. *Example.* — Suppose a building to contain 5873 square feet, how many bricks will build it, supposing the walls to be $1\frac{1}{2}$ bricks thick ?

4000 feet will require	-	-	-	66,176
800 “ “ “	-	-	-	13,235
70 “ “ “	-	-	-	1158
3 “ “ “	-	-	-	49
<hr/>				
4875				80,618

Plastering. — In New England, and almost all other parts of the country, the stone and brick mason is a plasterer, to whose art we are indebted for a considerable portion of the effect produced by the decorative part of architecture. The art of the plasterer is necessary in the proper finish of all kinds of building.

Great care is requisite in the preparation of the mortar, or *stuff*, as the workmen call it; the lime should be thoroughly slacked, or *soured*, before the sand and hair are added. Unless the lime is completely slacked it is impossible to make smooth and durable work; the best burnt lime will require the maceration of several days.

In making mortar for plastering, some other substances are frequently added besides lime, sand, and hair, according to the nature and uses of the walls to be plastered.

The most common cement used for plastering the inside walls of buildings, common mortar, is called *coarse stuff*, and is prepared in the usual way with the addition of hair.

Next to this is *fine stuff*, which is formed by first properly slacking the lime with a small quantity of water, after which a large quantity of water is added to it in a tub, where it should remain until the water has so far evaporated as to leave the lime of a proper consistency for use; commonly about three parts of fine sand is added to three parts of this lime, and sometimes a little hair, and is then called *trowelled stuff* or bastard stucco, and with this stuff all walls intended to be painted should be finished.

For the purpose of forming cornices and mouldings

with a wooden mould, a different cement is used ; it consists of fine stuff, as above three fifths, and plaster of paris one fifth, mixed with a proper quantity of water. But a small quantity should be made at a time, as it sets very quickly. Where great expedition is required the same stuff is used for other plastering.

Plaster of Paris, known also by the names of gypsum, and sulphate of lime, is an important material in plastering. The best method of preparing this substance for the use of the plasterer, is to select the purest kinds and burn them in a proper place, by which means the water and sulphuric acid are driven off, after which the stones are powdered fine, when it is fit for use. Care is requisite in the calcination ; too much or too little injures its qualities, and causes it to become soft on exposure to the air. It is known to be well burned, if, on mixing it with water, it has a soapy and sticky feeling to the fingers. If it has not these qualities it is not worth using. As burnt plaster loses its qualities by exposure to the air, it should be used fresh ; and in places which do not furnish this material, this stone should be procured and calcined as wanted.

Stucco is a very neat kind of work, and is principally used for the interior of buildings in this country ; in France and Italy it is used also for covering the exterior, but this kind of work will not bear the cold of our climate for exterior decorations.

Various cornices and ornaments are formed of this substance for interior decorations, by means of moulds made of wood ; Basso-relievos and friezes are made of the same material by casting them in wax moulds ; these moulds are made from clay moulds, by forming the latter by hand and then running melted wax into them. The capitals of columns are formed in the same manner, only requiring numerous moulds to complete them.

Fresco-painting or staining, is sometimes applied to outside walls to give them the appearance of stone, and is performed in the following manner. The walls are first covered with Roman cement, after which they are washed over with a mixture of diluted sulphuric acid and water, to which a fluid-ochre of the required tint is added : by this means the color is fixed and permanent,

because the acid unites with the iron which is in the cement, and fixes the color.

There is a distinct branch of plastering invented, and much used in Italy, and from thence introduced into France and England, where it is much used for interior decorations, it is called *scagliola* from the Italian word *scaglia* (*a chip of marble*); it is sometimes called *marbling*, from its imitating marble. This kind of work is principally used for columns and pilasters (*half columns*); for this purpose a frame of wood is made and lathed about $2\frac{1}{2}$ or 3 inches less in diameter than it is intended to be when furnished; the lathes are covered with common plastering mortar. When this is *pricked up* or roughened by crossing it with a lathe, so as to make the next coat stick, and is sufficiently dry, the worker in *scagliola* commences.

In preparing the materials for this kind of work, the purest plaster of paris is necessary, and should be reduced to a fine powder: it is mixed with a solution of glue, isinglass, &c. In this solution the required colors are mixed, and when the work is to be of several colors, they are mixed separately, and afterwards mingled and combined as required. It is *float*ed like other plastering by means of proper moulds: after which it is polished with pumice stone, it is then rubbed with tripoli, (*a good kind of rotten stone*) charcoal, and a piece of linen, afterwards with a piece of felt dipped in a mixture of oil and tripoli, and finally with pure oil.

In this way the most precious marbles and other costly stones are imitated with astonishing and delusive effect; as the imitation takes as high a polish, and feels as cold and hard as the most compact marbles, nothing beyond actual fracture can possibly discover the deception. If the capitals of columns are made of real marble, the deception is beyond discovery. If not exposed to frosts and moisture, its durability is little inferior to that of marble, it retains its polish as well, and is not one tenth of the expense of the coarsest kind of marble.

In plastering the walls of buildings constructed of stone or brick, the cement or plaster should never be laid upon the stone or brick, if it is, the building will always be damp; therefore, the plastering should be placed on

lathes nailed to pieces of wood called *furrings*, leaving a space between the wall and plastering. This is the common practice in this country and is founded upon the following principles of heat. Brick and stone being bad conductors of heat, stone or brick houses are warm in the winter and cool in the summer, and if warm air (which is always charged with moisture) comes in contact with a colder body, as stone or brick, the moisture is condensed upon the cold body in the form of water: now apply the principles to a room in a stone or brick house, the moisture of the room is condensed by the cold walls. If a confined space of air is left between the wall and plastering, air being a bad conductor of heat, the cold of the brick or stone does not reach the plastering, therefore such houses are never damp—because the moisture can never come *through* the walls, if properly constructed.

White-washing and coloring is another part of a mason's work, and consists in laying a thin coat of lime upon any surface, either its natural color, white, or any other. Lime washes for stone, brick, or plastering should be made by slacking lime with pure *fresh* water, as salt water would cause it to exfoliate or peel off, and a small quantity of lampblack should be added, (previously killed in vinegar) as this deprives the lime of its yellow tint. Where wood work is to be washed, the lime should be slacked with *salt* water, as this gives it a better set than fresh water would, and will prevent its peeling off.

Thus, we have gone through with a practical explanation of the principal materials used by the mason, and a short illustration of some of their uses; our object has been solely to explain the rationale of their operations, to give a few of the *whys and wherefores*: if these are properly understood by the masons of our country, we willingly leave the manual part of their art to the well known ingenuity of our countrymen, with a sure pledge that our country will not be wanting in monuments of their skill and intelligence.

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EVAPORATION.

THIS is a process which is continually going on around us. The earth is alternately dried and replenished with moisture, — the streams shrink and grow again, — vegetation at one time mourns the absence of her genial nourisher, and at another glows with renovated life and vigor ; — all these changes are the effects of evaporation. Often on one day the weather is fair and clear, and the sun goes on 'rejoicing as a strong man to run a race.' The next day, the face of the heaven is veiled in clouds, and the drenching rain or chilling snow is rapidly descending. In the morning, nature is smiling beneath the light of day, and before the shades of evening have fallen upon the landscape, the tempest has risen in its wrath, and the thunder is echoing through the sky. What is the agent that has produced this transformation ? What is it, that at one time forms the materials for the tempest, and at another, creates the golden clouds that gather around the path of the descending sun ? It is evaporation. It is this that dries the face of the ground in spring, gives the beautiful greenness to the fields of summer, and prepares the materials for the snows and storms of winter. Scarcely less important are the effects of evaporation on domestic economy. To the painter, the clothier, the calico-printer, it is indispensable ; to those engaged in the daily routine of domestic avocations, no less so. They all rely upon it with implicit confidence, nor do they rely in vain. For thousands of years it has been employed, and still it performs its destined task, as faith-

fully as when its operations first began. Let us then examine this operation of nature, so important in its effects, so interesting in regard to the phenomena by which it is attended.

We will first inquire into the *cause* of evaporation. Heat appears to be the great agent, by which the process is carried on. Perhaps the air itself may have some tendency to raise water; but various experiments prove the great influence of heat in the formation of vapor. An illustration of this may be seen in the rapidity with which the ground dries after a rain in summer, compared with the slowness of the same process in autumn or winter. When the temperature of water is raised above 212 degrees, it assumes the form of vapor so rapidly as to cause that bubbling which we term boiling. This process differs in some respects from the formation of vapor at the common temperature of the atmosphere. The distinction between them is sometimes expressed by the terms vaporization and evaporation. There is however so much connexion between them, that we may with propriety examine them together. Water may be made to pass off entirely in vapor, though kept at a temperature far below 212 degrees. Moisture collects on the cover of a kettle, when placed over the fire, long before the liquid has reached the boiling point. But it is not till it has reached that point, that the expansive power of heat is sufficient to enable the water to assume the form of vapor, while pressed by the superincumbent liquid. At that point it becomes sufficient, and the water near the bottom expanding into vapor, and rising rapidly to the surface, causes the appearance, which is termed boiling. On high mountains water boils at a much lower temperature than in valleys. The pressure of the air on the surface of the water is less, and consequently the resistance to the formation of vapor is diminished. On the top of Mont Blanc, the highest of the Alps, water boils at 187 degrees. In the exhausted receiver of an air pump, it boils at a still lower temperature. Ether is so volatile that it boils at almost any temperature, when the pressure of the atmosphere is removed. If a watch-crystal containing a little ether, be placed in another

containing a few drops of water, and the pressure of the air upon the surface of the ether be removed by the air-pump, the ether will boil and the water will freeze. The heat which the ether absorbs in boiling causes the water to freeze. From the same cause, wetting the hands with ether will make them severely cold. The ether evaporating takes away heat from the hands.

The fact that liquids are driven off or made to boil at lower degrees of heat when the pressure of the atmosphere is lessened or removed, has recently been applied to some very useful purposes.

The process for refining sugar is to dissolve impure sugar in water, and after clarifying the solution to evaporate the water that the dry, crystallized mass may remain. Formerly this operation was conducted under atmospheric pressure, and a heat of 218 or 220 was requisite to make the syrup boil:—by this heat a portion of the sugar was often discolored and spoiled, and often the whole was more or less injured. The thought occurred to Mr Howard that this evil would be remedied, if the water were dissipated by boiling in a place from which air was excluded, as the temperature then required would be so low as not to injure the sugar. The plan proposed by him was tried and succeeded; and the saving of sugar and the improvement of quality were so great as to make the patent right, by which the emoluments of the process were secured to him and others, worth several thousand pounds a year. The syrup, during this process, is not more heated than it would be in a vessel merely exposed to a summer sun. This is an interesting instance of the application of philosophical principles to purposes of practical utility.

The process of distillation affords another instance. This process consists simply in bringing the more volatile parts of any substance by means of heat into an æriform state, and then condensing them again in appropriate vessels. Many substances which are changed and injured by high degrees of heat, may be obtained of very superior quality by carrying on the operation in a vacuum. The essential oils of lavender, peppermint, &c, never had the natural flavor and virtues of the plants themselves, until

since a plan based on this principle was adopted. In many instances the influence on the human system of vegetable medicines thus obtained is so different from that of the old preparations, that this principle becomes one of the utmost importance to the medical practitioner.

The expansive force of steam is prodigious. At 212 degrees, the point at which water boils under common atmospheric pressure, the force of steam is, as might be supposed, 15 pounds to the square inch, or equal to the pressure of the atmosphere. Above this temperature it increases according to the following table :

At 250 it is 30 pounds per inch.

“ 272 “ “ 45 “ “ “

“ 290 “ “ 60 “ “ “

Seeing the rapid increase of the expansive force in the above table, we have the explanation of the terrible effects occasionally produced by confined water, when overheated. A boiler of any kind, if completely closed and having no safety valve, will explode as if charged with gunpowder. And against such a disaster, no strength of materials is a sufficient protection without care and skill on the part of those who have the management of this mighty agent ; but with these it may be made, notwithstanding its tremendous power, to perform its part almost if not quite as safe, as the beast of burden that we consider completely under our control. Unhappily the instances are too numerous, in which the incautious or ignorant use of steam has produced explosions, which have shattered buildings, and sometimes destroyed whole neighborhoods. The principle on which the steam engine acts is not difficult to be understood, although it is often supposed to be intelligible to those only who will devote much time to the study of it. He who can understand a pump, can understand a steam engine. It is in fact only a pump in which the fluid is made to impel the piston instead of being impelled by it, — that is to say, in which the fluid acts as the power, instead of being the resistance. It may be described simply as a strong barrel or cylinder with a closely fitting piston in it, which is driven up and down by steam admitted alternately above and below from

a suitable boiler. The power of the engine is of course proportioned to the size or area of the piston, on which the steam acts with a force according to its density, of from 15 to 100 or more pounds to each square inch. In some of the mines in Cornwall, England, there are cylinders and pistons of more than 70 inches in diameter, on which the pressure of the steam equals the effort of 600 horses. So extensively is this engine used in England, that it is an important source of her national power. There one engine is often seen stretching its long arms over an extensive manufactory, and guiding all its complicated movements seemingly with the precision and more than the precision of intellect. In one part of the building it is keeping thousands of spinning-wheels in motion, while in another it is carding the material, and in a third weaving the cloth. In like manner, one steam-engine in a great brewery may be seen at the same time grinding the malt, pulling up supplies of all kinds from wagons in various situations, pumping cold water into some of the coppers, sending the boiling wort from others into lofty cooling-pans, over which it is turning the fans, and in a word, performing the offices of a hundred hands. It is not strange that the eulogist of Watt, the great improver of the steam engine in England, should say, 'it is the steam engine which has fought our battles and enabled us to come off victorious in the late tremendous contest.' Had it not been for this mighty engine, perhaps England herself would have been compelled to bend under the power of Napoleon, aided as he was at one time by the power of almost all Europe.

Water, if not confined, slowly evaporates and incorporates with the atmosphere at any temperature above the freezing point. And it is highly probable that even freezing does not wholly put a stop to this process. Ice appears gradually to waste away even when the surrounding air is at a temperature far below the freezing point. When water is rarefied to a certain degree, it becomes lighter than the surrounding air, and consequently rises, although its presence in the air is not generally perceived. The air can contain a certain quantity of moisture so dissolved as to be perfectly invisible. In this state it

occasions no dampness. The quantity which it is capable of so containing, varies with the warmth and density of the air. It decreases 'from below upwards, and from from the equator to the poles. The air has been compared to a sponge, expanding and becoming capable of containing more water, by heat, and contracting by cold.' Air at the freezing point can hold in solution $\frac{1}{160}$ of its own weight in water: at 59° , $\frac{1}{80}$, at 86° , $\frac{1}{40}$, and so on, its power doubling at every increase of temperature equal to 27 degrees. — In a hot summer day, the air holds a great quantity of water in solution; yet we are wholly unconscious of its presence unless it is by some means deprived of its heat, and thus rendered visible. If, in a warm day, a tumbler be filled with cold water, the outside of it will almost immediately be covered with dew. The tumbler being colder than the surrounding air, takes away a part of its heat, and the moisture which that heat kept in solution is rendered visible on the outside of the tumbler. When the dew thus deposited is very abundant, it is justly regarded as a sign of rain. Other things being equal, the quantity deposited will be in proportion to the amount of water then held in solution by the air. If this amount is great, a small change in the state of the air may produce rain. If it is small, a greater change will be necessary, and consequently the probability of rain is less. But vapor sometimes rises in so great quantities that the air cannot dissolve it all. Sometimes by a change of temperature, or some other means, the air loses a part of its power to contain water in an invisible state. A part of the water will then become visible in the form of a cloud.

CLOUDS.

Clouds, then, are collections of vapor in the air, rendered visible by condensation. They seldom rise very high. Sometimes they rest upon the earth's surface, constituting what is termed fog. Sometimes they are a mile above the surface of the earth, sometimes more; but they seldom rise higher than two or three miles. Very thin fleecy clouds, however, sometimes rise to the height of 4 or 5 miles. But why do they not rise to the surface of

the atmosphere? — The density of the atmosphere rapidly decreases upwards. One half of the whole quantity of air is within about three miles from the earth. Above this height, the air is unable to support any considerable quantities of vapor. Hence we see the reason why clouds rise no higher, and why the thinnest and lightest rise highest.

Form and Color of Clouds.

To an attentive observer the clouds present many interesting subjects of contemplation. Their ever varying forms, their beautiful and richly variegated colors, and their silent motion varying often in velocity and direction, while they furnish the poet with a field in which his fancy may rove delighted, also afford to the student of nature, many an interesting theme for reflection. At one time, dark and portentous, fancy might easily imagine them the ruins of some ancient castle, or time-worn tower. At another, they gather in beautiful and glorious forms around the path of the descending sun, and seem to vie with that luminary itself in splendor. Sometimes they move swiftly over the face of heaven, and soon recede from our view; sometimes they seem to meet each other, and soon, like hasty travellers, pass each other by, without a sign of recognition. At one time while we gaze upon them, they vanish; at another they gather into darker and heavier masses of collected gloom. Now they collect, now they disperse, — and now they change form and color with surprising rapidity. To the inquiring mind the question naturally occurs, what is the cause of all these varied appearances? The inquiry leads to careful observation, and though in many instances, that cause clouds our search, yet, in many others, we are enabled to arrive at general principles and uniform relations, which enable us to anticipate the storm, and predict the time of its termination. The principal circumstances which influence the form of clouds are the motion of the air and the formation and condensation of vapor. Substances so light as clouds, readily change form, when subjected to greater atmospheric pressure on one side, than on the another. Different portions of the air move with

different degrees of velocity. Hence clouds situated in these portions of air, divide, collect, and change form, according to the force acting upon them. Water-spouts are usually attended by a thick black cloud, formed probably by the vapor condensed by opposite currents of air meeting. New accessions of vapor often change the form of clouds; also the dissolving of vapor or a diminution of its density. Sometimes probably a cloud meets with a stratum of air sufficiently warm to dissolve it. In this case it will vanish by degrees. Different parts of a cloud may be in strata of air of different warmth or density. The cloud will then partly dissolve, and the part dissolved will perhaps rise and become visible in a higher portion of the air, where the heat is not sufficient to render it invisible. In the spring it is often cloudy in the morning, and clears off towards noon. The heat of the sun dissolves the moisture which arose in great quantities from the damp earth in the morning.

Clouds near the horizon generally appear to extend much farther horizontally than perpendicularly. This is probably, in part, an illusion. If the lower surface of a cloud is nearly parallel to the surface of the earth, its extent towards the zenith will appear much less than it really is, while this will not be the case with its extent in the direction of the horizon. As it approaches the zenith, it will appear more nearly of its true dimensions. Hence clouds in the zenith seldom, or never appear to be of this form. Clouds often move in opposite directions. Different portions of air often move in different directions above one another, on account of their being unequally rarefied by heat. They of course carry the clouds with them. This may be readily illustrated. If, in cold weather, the door of a warm room be opened a little, and a candle held near the bottom of the opening, and another near the top, the flame will often be blown in opposite directions. The cold air rushes in at the bottom, and the warm air being lighter goes out at the top.

The color of clouds depends on the rays of light which they reflect. Dark clouds often precede wind. But although they are seen before the wind is felt, they are not the cause, but the effect of the wind. As the wind moves on, it presses upon that portion of the air, which

has a velocity less than its own, and by this pressure, and perhaps also by its greater coldness, condenses the vapor contained in it, and thus forms a cloud. This cloud, being so dense that little or no light can pass through it, appears black. And the degree of darkness on the density of the vapor, or in other words, on the velocity of the wind, and the quantity of water in the portion of air compressed. The beautiful colors, that often adorn the sky at sunset, are caused by the clouds reflecting the sun's light. That redness of the sky in the morning, which is often regarded as the precursor of a storm, probably results from the red rays of the sun passing through the vapor collected in the air. Light is composed of seven different colored rays, possessing different degrees of force. These may be seen separate from each other in the rainbow. Of these the red rays have the greatest force or momentum. Hence, when the air is very full of vapor, the red rays have sufficient power to penetrate it, while the others have not. Many of the red rays, however, do not come directly from the sun, but are scattered in various directions on striking the vapor, and thus the redness is diffused over a considerable space.

Thunder-clouds exhibit an appearance peculiarly striking. To many they are objects of terror; in a greater or less degree they arrest the attention of almost every one. These clouds are collections of vapor strongly electrified. They are generally very dense, and very near the earth. Frequently two clouds rise in different parts of the horizon, and move towards each other, till they meet, at the same time rising up towards the zenith. When clouds in different electrical states approach near each other, or when a strongly electrified cloud approaches near to the earth, the electricity is discharged in vast quantities and with tremendous violence, thus constituting what is termed lightning, while the concussion given to the surrounding air by its force, and the rushing together of the portions of air separated by its motion causes thunder. This sound, reflected and reverberated among the clouds, produces the long-continued and solemn roll, which forms one of the sublimest characteristics of a thunder-storm. It is often imagined that lightning always

moves towards the earth. But there is reason to suppose, that discharges are sometimes made from the earth to the clouds, as well as from the clouds to the earth. — It is not difficult to measure the distance of thunder-clouds from the earth. Sound moves at the rate of 1142 feet in a second; light at the rate of about 200,000 miles in a second. The time in which light traverses so small a space, as that between a thunder-cloud and any place, from which the thunder can be heard, is so short that it need not be estimated. If then we multiply the number of seconds between the flash and the thunder by 1142, we have the distance of the cloud in feet. Hence, when a very short time elapses between the flash and the thunder, the discharge is very near. There is a peculiar sublimity attending thunder-storms in mountainous regions. The traveller among the Andes frequently hears the thunder roll, and sees the lightning flash from the clouds that gather around the hills far beneath him, while around his path, and on the heights above him, the sun is shining with unclouded splendor.

RAIN.

As the quantity of water in the clouds is increased by new accessions of vapor, they at length become too heavy to be supported in the air, and begin to sink. Often also the air below them grows lighter, and consequently less able to support them. They will then descend without any increase of weight. On this principle, the falling of smoke indicates rain. It seems a very fair conclusion that if the air is not sufficiently heavy to carry smoke up, it will soon let the water which it contains, come down. The barometer usually sinks before rain, showing that one great cause of storms is a diminution of the weight of the atmosphere. As the vapor descends, it will meet with other portions of vapor, and by degrees turn into drops of rain. To exhibit the process in a clearer light, let us suppose a few particles of vapor suspended high in the air, and strata of vapor arranged horizontally below. As each particle of the higher vapor passes through the strata below, a portion of the water in those strata, will unite with it: thus a drop will be formed. As the air

contains more or less water, and as the clouds are higher or lower, the drops will vary in size. Perhaps we may hence discover a reason why large drops are considered a sign, that the rain will not last long. Large drops, it is supposed, come most generally from elevated clouds, and the reason why they are large is, the number of particles accumulated during their passage through so large a portion of the atmosphere. But at a height sufficient to form these large drops, the air is not heavy enough to support large quantities of vapor. Hence the rain continues but a short time. But when the clouds are low, the particles of vapor, passing through but a small space, do not coalesce in sufficient numbers to form a large drop. The air near the earth being dense, can support more vapor. Hence the storms from these clouds are long. But thunder-clouds are low; yet the rain from them often comes in large drops, and does not generally continue long. These clouds are formed of very dense collections of vapor, so that in falling a short distance, a number of particles sufficient to form a large drop come in contact. In addition to this, the concussion given to the clouds by the motion of electricity, probably serves to condense the vapor still more. There is another marked difference between thunder-clouds, and those which produce long storms. The former extend over but a small space: the latter sometimes cover a large part of a continent. This will account for the difference in their duration. In addition to this, during a storm clouds probably often receive fresh accessions of vapor from places beyond the limits of the storm. Daily experience shows that the duration of storms depends very much on the direction of the wind. Winds which blow from the ocean, come loaded with vapor, which contributes to swell the amount already collected, and consequently to prolong the storm. Hence clear weather succeeding a storm, while the wind still continues in the northeast, east, or southeast, is seldom of long continuance. The wind soon loads the air again with vapor, and another storm is the consequence. On the contrary, north-northwest and west winds usually bring fair weather. They not only drive the clouds towards the ocean, but coming from a colder region into a

warmer one, they become capable of holding an additional quantity of water in solution, and therefore take this additional quantity from the clouds, that come in their way.

HAIL, SNOW, ETC.

Hail is caused by drops of rain passing through air sufficiently cold to freeze them. It is said to occur principally in the temperate zones. In the torrid zone it is seldom or never cold enough to form hail so near the earth as the clouds usually are, and should hail be formed in the higher regions of the atmosphere, the great heat which it would encounter in descending would probably melt it. In the frigid zones, on the contrary, the intense cold would freeze the vapor, before it had formed into drops; and during the few days of summer in those zones, the rapidly increasing heat renders the air capable of holding so much water in solution that the weather is generally pleasant. But in the temperate zones, which are exposed to currents of warm air from the south, and of cold air from the north, drops of water are often frozen after attaining a considerable size. The coldness of air generally increases in proportion to its elevation, but sometimes a higher stratum is warmer than a lower one. Hail-stones frequently result from such an inversion, and, as might be expected under such circumstances, are generally attended by wind. The wind, particularly in the torrid zone, blows from the poles towards the equator. The warm air at the equator rises, and flows back to restore the equilibrium. As it flows back, it grows colder. If it is so full of water, that on cooling it will deposit a part, the water thus deposited will pass through the current of air below, moving from the poles, and if this is sufficiently cold to freeze it, hail will be formed. It is believed that hail is generated in the higher regions of the atmosphere. Warm air is lighter than cold air, and will therefore tend to rise higher. Air, that passes swiftly from a warm region to a cold one, will have less time to cool in passing, than if it passes more slowly, and therefore will rise high, and pass on, till it comes in contact with very cold air, before it will deposit the water

which it contains. This water, in passing through a very cold stratum of air, will freeze. Again, a very cold current of air may suddenly meet with a body of air much warmer than itself, and freeze it. The hail-stones at first will be small. As they descend, they will freeze the particles of vapor, with which they come in contact, and thus grow larger. Observations made in elevated situations show that they do thus grow larger. — In the winter the vapor, as it condenses, is probably frozen before it forms into large drops, and thus becomes snow. Hence, when particles come together, they do not unite into one dense mass, as in rain and hail, but each particle exhibits its own formation and structure, and even when hail is formed in winter, the hail-stones are very seldom large. Hail-stones are generally hardest in the centre, and of a looser texture towards the outside. In passing through successive portions of vapor, the intense cold of the hail-stones is gradually diminished, and consequently those particles, which unite with them last, are not frozen so hard, as those which coalesced at an earlier period. It is frequently the case, that it snows on mountains and rains in valleys at the same time. Here we have evidence that the condensed vapor, during a part of the period of its descent, had the form of snow, and retained it, till it had descended as low as the tops of the hills, but melted in descending into the valleys. Hence the tops of the White Mountains and many others are robed in white, long before snow begins to fall in places near the level of the sea. Probably many of the rain-storms, which we experience, would be snow-storms to one who should ascend a mile or two in the air.

DEW.

As the earth cools more rapidly than the air, when it ceases to receive heat from the sun, the moisture, which is contained in the portion of air in contact with the earth imparts heat to it, and becomes condensed in the form of dew. When the cold is great this condensed moisture freezes, forming what is termed white frost. Dew collects most abundantly on those substances which give off heat most rapidly, as the difference between the warmth

of these and that of the atmosphere is the greatest. Hence we may see the reason why dew is more abundant in some places than in others. The soil being composed of different materials, gives off heat with different degrees of rapidity. It may perhaps seem surprising, that so much dew should be deposited from so small a quantity of air, as that which comes in contact with the earth; but the quantity of water deposited on a tumbler of cold water in hot weather, shows that a small portion of the atmosphere may hold in solution an amount of moisture by no means inconsiderable. It might perhaps seem that more dew would be deposited in very windy nights, than at other times, but generally this is not the case. Probably the particles of air are not in contact with the earth a sufficient length of time to lose much of their heat, and consequently continue to hold in solution most of the water combined with them.

It is often remarked that on cloudy nights there is little or no dew. This may perhaps be explained as follows:—There is a tendency in heat to diffuse itself uniformly among bodies by a constant radiation from one to another, which is rapid in proportion to the differences of temperature. Bodies therefore differing widely in temperature are soon reduced to nearly the same degree. When there are clouds in the atmosphere at night they receive the heat darted upwards from bodies on the earth's surface, and throw it back again to the earth; thus keeping the atmosphere near the earth warmer than it would otherwise be. But in clear weather, the heat thus sent upwards finding no obstacle to intercept its progress, darts away into boundless space, and is lost altogether to the objects which emitted it. Probably the sultry oppressive heat which is sometimes felt on cloudy days may be attributed to the same cause.

EFFECTS ON TEMPERATURE, CLIMATE, ETC.

The effect of evaporation on temperature is strikingly exhibited in the refreshing coolness, which generally follows a summer shower. As heat is the principal, if not the sole agent in the process of evaporation, the rapid evapora-

tion which succeeds a shower in summer, causes that grateful coolness, which is so generally felt after such showers — 'Though the heat, by which vapor is raised, is given out again, when that vapor is condensed into rain; yet it is not generally felt by us, as it remains mostly in that region of the air where the condensation causing the rain took place.

A room may be made quite comfortable even in the hottest weather, by keeping the floor wet. The water will rapidly evaporate, and by evaporating absorb so much heat, as to render the room comfortably cool. In India, by an application of this principle, they even produce such a degree of cold as to freeze water, though at the same time the temperature of the air is several degrees above the freezing point. Water is exposed to the air during the night in large shallow dishes, and by its evaporation carries off so much heat, that what remains in the morning is found covered with a thin coat of ice.

It is well known that islands and places near the ocean are warmer in winter, and cooler in summer than others. For an explanation of this fact, we must refer to the principles of evaporation. In summer, much of the heat is employed in converting the water of the ocean into vapor, and consequently the air is cooled. In winter, the ocean retaining a portion of the heat which it absorbed in the summer, and having parted with it less rapidly than the land, gives it off by degrees, and thus moderates the severity of the cold. The desert of Sahara has long been distinguished for its wide extent of barren and inhospitable sands. In the torrid zone, in which this desert is principally situated, the wind blows constantly from the east, or some point not far from east. The vapors brought by it from the ocean are arrested by the mountains of Abyssinia, and there descend in torrents of rain, which go to swell the waters of the Nile and fertilize the fields of Egypt. As there are few or no inland seas in Africa, there are no sources from which vapor can be obtained to furnish rain for the desert. Hence plants find no nourishment, and consequently cease to grow, and the whole region becomes a desolate and barren waste, except where some spring, fed by subterranean streams or reservoirs, diffuse its vivifying influence around for a few rods, and supplies the plants which

grow upon its borders, with the nourishment which they require. From a similar course, probably results the fact that it seldom or never rains in Peru. But this country is so near the ocean, that the water which rises from the ocean produces copious dews, which in some measure supply the want of rain, and thus save the country from utter sterility. Hence also a narrow strip of land, termed Azanaga, between the desert of Sahara and the ocean, is comparatively fertile.

The northwestern part of the United States owes much of its fertility to the great lakes Superior, Huron, &c. These furnish a quantity of vapor to supply the deficiency, which would otherwise result from the great distance, at which the States in this section of the country lie from the ocean. Were these lakes to be dried up, the people of those states would soon feel the effects in the diminished quantity of rain, which they would receive, if not in seeing utter desolation spreading over their now beautiful fields. In warm countries, even where rain is common, plants often suffer for want of moisture. In some parts of Spain, the fields often appear almost as if a fire had passed through them; vegetation becomes parched and dried, as the heat of the summer sun and often the winds blowing from Africa carry off the moisture with very great rapidity. In such countries, however, vegetation, when plentifully watered, and sheltered from the burning heat of the sun sufficiently to prevent too rapid evaporation, exhibits a luxuriance, which would seem surprising to an inhabitant of more northern regions. There, nourished by the combined influence of heat and moisture, the palm, the magnolia, and other gigantic sons of the forest, raise their lofty heads, arrayed in perpetual verdure; while the forests, often rendered impenetrable by vines and bushes of various kinds, bear witness to the powerful influence of that agent, which dresses the fields of the temperate zones in less luxuriant, but perhaps not less beautiful verdure. In the frigid zones, where, during a great part of the year, water scarcely exists in a fluid state, evaporation is very scanty, and this, together with the intense cold, prevents the progress of vegetation, except during the few weeks of their brief summers.

The influence of cultivation on climate and tempera-

ture is very important, and this influence is exerted in a great measure through the medium of evaporation. — Forests are the abodes of dampness. As these are removed, the bogs, morasses, &c, which they contain, are dried up, and no longer give rise to cold and dampness by absorbing heat, and loading with vapor the air which passes over them. Trees prevent heat from penetrating the earth, and thus render a country in which forests abound cooler than one in which they do not. The decayed vegetation, which is constantly accumulating where the ground is covered with forests, presents a formidable barrier to the heat, which, were it not for this, would penetrate the earth in summer, and be given off to mitigate the severity of winter. — The climate of Europe is well known to be much milder than it was 2000 years ago. Roman writers speak of snow-storms and ice as common in their days, in countries, the inhabitants of which would now be almost surprised to see them. Even in New England it is generally thought that the climate has grown sensibly warmer since the country was settled. Whether this amelioration is wholly to be ascribed to the cause which we have mentioned, may perhaps be doubted; but that the influence of evaporation is great, few will question. So extensively indeed is its influence connected with changes of temperature, and the growth of plants, that whatever tends to throw light on this connexion well deserves the attention of the agriculturist and the philosopher.

DOMESTIC ECONOMY, ETC.

The avocations of the husbandman, and the employments of domestic life depend, in many instances, on the operation of nature, which we are now considering. It is evaporation, which removes the superfluous moisture from the ground in spring, prepares the new-mown hay for the barn, and makes ready for use the apparel that has tried the cleansing power of water. It is this that seasons the timber of the carpenter, dries the mortar of the mason, and gives permanence to the effects produced by the skill and labor of the painter. The same agent causes some substances to crumble to powder, and others to become

moist or liquid on being exposed to the air. Common pearlash is moistened by being exposed for a short time to the action of the atmosphere. Having a strong attraction for water, it absorbs it from the air, and becomes moist, and ultimately, if allowed to stand a sufficient length of time, liquefied. On the other hand, some substances have so little attraction for water, that they readily give off to the air that which they at first contained, and thus crumble into powder. These two properties are often distinguished by the terms deliquescence, and efflorescence.

INTERESTING PHENOMENA RESULTING FROM EVAPORATION.

Many interesting appearances in nature are connected with evaporation. A few of these we will notice. The reflection of light from vapor is perhaps one of the most interesting of these. Among the Hartz Mountains, in Germany, there are places in which a person may see his own image in the air almost or quite as distinctly as in a mirror. A light breeze of wind will destroy it, but it will appear again, soon after the wind has passed. A curious phenomenon, probably resulting from a similar cause, acting under different circumstances, has been noticed in the great American Desert. The ground at a distance appeared to be covered with water, in which objects could be distinctly seen reflected, as they generally are from still water, but on approaching, no water was to be found. In the deserts of Arabia such an illusion often mocks the hopes of the thirsty traveller. There is, however, some difference of opinion in regard to the cause of this last phenomenon. It is often observed at sea, that when the air is full of vapor, objects appear very large, or 'loom up,' as the sailors term it. For an explanation of this fact we must refer to the principles of Optics. From these we learn, that when light passes out of a rarer into a denser medium, those rays which do not strike the denser medium perpendicularly, are bent so as to make them nearer perpendicular to the denser medium. Now the air is thickest, and therefore capable of containing most moisture near the earth. The rays of light therefore in passing through the vapor are bent downwards,

and appear to come from a point nearer overhead than they really do. Consequently the object appears higher than it really is, and as we judge of the distance of objects by their apparent size, nearer. A similar appearance is sometimes witnessed, though perhaps not to so great an extent on land, when the air is full of vapor. Hence it is a common remark in some places, 'We shall have rain soon, for the hills look near.' The different situation of hills, &c, makes this appearance more noticed in some places than in others. It is well known that fog when it is dense, almost wholly obstructs vision. It has been asked why this should be, as fog is composed of water, which is transparent. Those, however, who have observed the appearance of an object, when viewed through a globular vessel of water, can easily imagine the effect produced by millions of exceedingly small globules, such as constitute fog. The principle of Optics, on which this is explained, is mentioned above, but it is necessary to mention that if the surface of the denser medium be convex, the rays of light, in beaming nearer perpendicular to that surface, are bent towards each other. This may be seen in a common burning glass. If we should attempt to look at an object through a pile of ten thousand little balls of glass, we probably should not be much better able to see it, than we are to see objects through fog.

Those who live near the Cape of Good Hope often witness a striking phenomenon illustrative of our present subject, when the wind blows from the southeast. 'Beyond the city, as viewed from the bay, there is a mountain of great elevation, called, from its extended flat summit, the Table Mountain. In general its rugged steeps, are seen rising in a clear sky; but when the southeast wind blows, the whole summit becomes enveloped in a cloud of singular density and beauty. The inhabitants call the phenomenon the spreading of the table-cloth. The cloud does not appear to be at rest on the hill, but to be constantly rolling onward from the southeast; yet to the surprise of the beholder, it never descends, for the snowy wreaths, seen falling over the precipice towards the town below, vanish completely before they reach it, while oth-

ers are formed to replace them on the other side. 'The reason of the phenomenon is, that the air constituting the wind from the southeast, having passed over the great Southern Ocean, comes charged with as much invisible moisture as its temperature can sustain. In rising up the side of the mountain it is rising in the atmosphere; and is therefore gradually escaping from a part of its former pressure; and on attaining the summit, it has dilated so much and has consequently become so much colder, that it lets go part of its moisture. This then appears as the cloud now described; but it no sooner falls over the edge of the mountain, and again descends in the atmosphere to where it is pressed and condensed, and heated as before, than it is re-dissolved and disappears; the magnificent apparition thus dwelling only on the mountain top.'

When the elevation, to which moisture is suddenly carried, is very great, the fall of temperature is proportional, and the separating water becomes snow instead of rain. A sudden reduction of temperature by other means will produce the same effect. This is curiously illustrated by a fountain used in one of the mines of Hungary; during the play of which the air is so compressed, that on being released it expands and cools itself enough to cause the moisture driven out with it to appear, even in summer, as a shower of snow.

At the time of the great eclipse of the sun in February last, it was observed in several different places, that although the sky was clear at the commencement of the eclipse, clouds began to appear before the middle, and continued to increase till the sun was almost or wholly hid from view. It was also observed that soon after the eclipse ended the clouds began to diminish in density, and that at length they vanished away. It is not difficult to account for these appearances on the principles of evaporation. As the heat received from the sun was diminished in consequence of the eclipse, it became insufficient to keep all the vapor contained in the air in an invisible state; the moisture therefore condensed and formed clouds. When the sun after the eclipse shone on these clouds, the heat thus communicated caused them to dis-

perse. If in some places the sky continued clear during the eclipse, the atmosphere in those places probably contained less moisture than those before mentioned, and was therefore able even at a diminished temperature to support it in an invisible state. In the town, in which the writer of this resides, it was observed that on and near a certain pond, it snowed constantly during the latter part of the eclipse, while at a distance from the pond no snow fell. In this case it would seem that the atmosphere over the pond was saturated with moisture, and that as the air over land cools more rapidly than that over water, the colder air from the land moved towards the pond and produced the condensation of vapor and the consequent formation of snow which was noticed.

Perhaps there is scarcely any operation of nature, which more strikingly displays the wisdom and goodness of God, than evaporation. Let this cease, and the earth would become a desolate waste, except where the laborious efforts of man might, by frequent watering, create a spot of verdure here and there, amid the desert. The important effects resulting from so simple a cause may well lead us to admire the wisdom and goodness of that Being who is 'wise in counsel, and wonderful in working,' and who 'maketh the sun to rise on the evil and the good, and sendeth rain on the just and on the unjust.'

The facts mentioned in the foregoing pages show that the subject of evaporation, especially when considered in connexion with changes of the weather and with meteorology in general, opens a wide and interesting field for reflection and investigation. And this field is open to all. Here he who will may study the operations of nature, and search for the principles by which those operations are guided and on which they are conducted.

To the reflecting mind it is ever a source of pleasure to be able to trace effects up to causes, and to ascertain the various relations which subsist among the works of nature. Indeed, who would not prefer the knowledge of a Franklin who could trace the lightning's path and guide it to the ground, to that of him who thinks there will be a thunder-shower to-day because the clouds look as they did last year before a thunder-shower, but who knows nothing

of the nature or cause of the magnificent display of power and grandeur, which he is about to witness.

It is a fact, which, were it not so common, would strike us with surprise, that multitudes, although nature is constantly exhibiting to their view interesting phenomena and beautiful illustrations of philosophical principles, yet pursue their way amid all her sublime scenery and interesting illustrations, unconscious that they themselves are thereby furnished with any means of intellectual improvement, or sources from which they may derive accessions to their stock of knowledge. — And it is a lamentable fact, that many teachers have yet to learn that the laboratory of nature is one of the most important objects to which they can direct the attention of their pupils. Many seem to imagine that when they have conveyed to those under their instruction, the ideas contained in a certain number of books, they have done all that is required of them. It does not even occur to their minds that the book of nature, which is open to the eyes of all who will read, contains any valuable instruction. But let them once become accustomed to directing the minds of their pupils to the operations of nature; — let them once familiarize themselves with the practice of referring to scenes and events around them for illustrations of philosophical principles, and they will find science in everything; — they will find it in the wind that sweeps over the hills, in the clouds that hang on the mountain's top, in the fire that burns on the hearth, and even in the fly that crawls on the window. Few things are more important for men and especially for teachers to learn, than that science is not to be considered as standing aloof from the common concerns of life, but that it is simply the explanation of facts and events which in different ages have arrested the attention of observing and reflecting minds. — The book of nature is open with lessons appropriate for all. A very simple problem in mechanics or hydrostatics presented by the operations of nature, may be as truly a source, and perhaps as great a source of mental improvement to one individual, as a much more difficult one to another whose mind is more expanded and better disciplined. Then let not him who cannot have access to the volumes in which

are contained the results of laborious research and scientific investigation, conclude that he is thereby debarred from all means of intellectual cultivation. Let him examine with a spirit of inquiry and investigation the scenes around him. Let him search for knowledge in the trees of the forest and the stones of the brook ; — let him lay nature under contribution to increase his stock of knowledge and he will find that her instruction is freely given, and that exertions made to gain knowledge carry their own rewards with them. Let it be proclaimed till it shall sound in the ears of every teacher who is not awake to that which is both his interest and his duty, that there is a way by which his instructions may be rendered doubly interesting and doubly profitable to those who are placed under his care. If he has become wearied by listening to the same dull sound of recitations, and has found his pupils not less so by conning over again and again the same lesson, let him lead them out into the fields of nature ; — let him vary and diversify his instructions by visible illustrations drawn from scenes and objects around him, and see if he does not find a new charm thrown over the objects to which his attention is directed. He will find such a course a source of improvement scarcely less important to himself than to his pupils. By the intellectual effort thus required, and the new ideas thus elicited, he will find that his own mind is expanded and enlarged, and that while he is endeavoring to enlighten the minds of those under his instruction, he is performing the same office for his own mind.

But it is not in Natural Philosophy alone that the intelligent and faithful instructor will seek to diversify and elucidate the principles of science, by familiar and varied illustrations drawn from objects around him. In almost every path of science, nature has scattered flowers, which the hand of the diligent and attentive lover of knowledge will not fail to gather. Human character and human actions are among the most interesting objects of contemplation that can be presented to the mind of man. While, therefore, the instructor, who loves his employment, will delight to refer to the material world for illustrations in

Natural Philosophy, he will see that the world of mind furnishes him with illustrations perhaps, not less extensive and interesting, pertaining to Mental Philosophy. The mind here has its laboratory within itself, and the dreams of the night, the actions and thoughts of the day, and the opinions and ideas brought to view by the ever fluctuating tide of popular opinion, will furnish him with many an interesting illustration of the laws of mind. Even in the sports of childhood, the attentive observer will find much that is interesting, much that elucidate the principles on which the mind of aspiring and intellectual man is wont to act. And many an important principle of the sciences which pass under the high-sounding names of rhetoric, logic, and intellectual philosophy, may receive simple and yet beautiful illustrations from the words and actions of the child, who, as yet, knows nothing of the sounding names by which those operations are designated in the halls of science.

If the above remarks are thought to be too great a deviation from the professed subject of this Tract, the writer can only reply, that they are such as suggested themselves to his own mind in connexion with the subject, and that he therefore inserted them, hoping that if they were not very closely connected with the subject, yet as they seemed to arise from it, they might be useful in exciting attention to the important principle of education which they are intended to enforce.

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ANIMAL MECHANISM.

THE EAR.

BY JEROME V. C. SMITH, M. D.

THE ear, that organ by which we are made sensible of the impression of sound, in the higher species of animals, is a very complicated instrument. It is a beautiful piece of mechanism, more intricate than a timepiece, and no less wonderful in structure, than the arrangement of the numerous pipes of a church organ.

It is a curious circumstance in the economy of organized beings, that the central portion of the human ear, termed the *saculus vestibuli*, hereafter to be described, is the basis of the apparatus of hearing in all animals with which naturalists are acquainted, with the exception of insects*, but becoming more and more complex as inferior grades approximate the physical perfectibility of man.

Sound being a vibratory motion of the air, first put in motion by a solid body, is collected by the ear as the pulsations travel onward, and transmitted directly to the auditory or seventh pair of nerves, — mere filaments, like two white cotton threads, which communicate the fact of these vibrations to the sensorium, — or, in other words, produce a corresponding change in the brain.

* The antennæ of insects are considered the only organs with which they are furnished, that convey a sensation analogous to hearing. By the vibrations communicated to the body, through these, they are probably made susceptible of simple sonorous impressions.

Taking it for granted, that the reader has already a thorough knowledge of the doctrine of acoustics, diacoustics and catacoustics, we shall steadily pursue that kind of popular philosophical examination of the ear, which has been the endeavor in a preceding essay on the mechanism of the eye.

Those beings only, which are denominated locomotive, having the power of moving themselves from one place to another, have an ear. 'The circumstance of the existence of this faculty, presupposes some sort of auditory contrivance, by which the creature can be made conscious of the certain existence of near foes, or its friends and species. Without this sense, of such vast importance to man, inferior tribes would be constantly exposed to dangers and even destruction — as they would necessarily be obliged to move towards an apprehended evil, to see it, in order to be certain. Nature has not been neglectful in granting the necessary means of happiness to every being, in proportion to its wants in the sphere in which it is destined to live; nor partial to man, in the development of all his senses, to the exclusion of other animals, whose physical propensities, necessities and circumstances are of as much importance to them, in the scale of existence, as his own.

EXTERNAL EAR.*

That appendage termed *auricula*, *pinna* or externa ear, peculiar to all the warm blooded quadrupeds, divested of the skin, is a thin, delicate piece of cartilage, quite elastic, and bearing some resemblance, in this respect, to parchment. On its outer surface, on such as carry the ear erect, it is generally concave, but thrown into deep semicircular grooves, which terminate in one large dish, surrounding the canal that enters the bones, called *concha*, because it resembles a shell. The lines, or eminences lying between the furrows, have definite names, as helix, antihelix, tragus and antitragus, and lastly, the fat pendulous portion, on the under edge of the ear, — in which trinkets are worn, occasionally, in civilized society, in humble imitation of genuine savage life, — the *lobus*.

* So called from *aura*, air.

Explanation of Figure 1.

This is a well marked ear of a man, drawn from life.

a to *e* — The *helix*, forming the rim.

a — The upper end or commencement of the rim, sloping into the concha.

b — Part of the edge lost in the face.

c, *d* — Prominent from the head.

e — The fold terminating in the lobule of the ear.

f to *m* — The *antihelix*.

f, *g* — The upper end divided into two ridges, — *h* the union of them, — *f* and *g*.

i, *k* — lower end of the *antihelix*, continued at *i* into the concha, and at *k* into *antitragus*.

l — The *tragus* covering the entrance to the ear — like a post at the corner of a street to prevent sudden injury.

m — *Antitragus*.

n — *Lobe* of the ear, usually bored.

oo — Furrow between the *helix* and *antihelix*.

p — The boat like depression between the lines of the *antihelix*

x — The *concha*.

r — The beginning of the *meatus auditorious*.

FIG. 1.

MUSCLES.

Although in the human species, there are muscles which seem at first sight to have been designed for moving the ear in different directions, their office is expressly to keep the cartilage tense, — equally on the stretch at all points, to increase its vibratory property. Occasionally, individuals are seen who have such development of the auricular muscles, as to be able to move their ears at pleasure. Wags and buffoons are sometimes expert in the exercise. Several physiologists have suggested that mankind, in these degenerate days, have lost the power of moving their ears, by wearing hats, bonnets and such like unphilosophical coverings for the head, and in corroboration, (by way of sustaining an argument,) make reference to some solitary examples of ancient statues,

on which the ears are represented as standing outward and forward. There are three of these muscles or cords.

FIG. 2.

Explanation of Figure 2.

In this plate is represented the muscles peculiar to the external ear.
a-d-e—The cartilage of the ear, as seen on that side looks towards the cranium.

f to p—The attolens aurem, or lifter up of the ear. *f-g-h-i*—the

upper end of it. *l-m* — shows where it becomes tendinous on the bones of the head. *o-p* — attached to prominences.

g to *t* — The *anterior auris*, placed between the face and ear. *q-r* — the portion of it connected to the muscle of the forehead, — growing narrower at *s*, and inserted into the *helix* at *t*.

u-z — Two muscles, or rather, two portions of one, *retrahentes aurum*, to draw the ear back from the face.

u-v-w-x — The upper or larger portion, consisting of fleshy fibres, *u, v, w*.

y-z — The inferior portion of the same muscle.

All such animals as keep their ears habitually erect, as the fox, lynx, cat, horse, ox, ass and various species of the dog, maintain them in that position by the strength of the muscles, which are thoroughly developed, strong and under the control of the will. Such as have this characteristic, are either timid, feeble, harmless creatures, or distinguished for their rapacity, cruelty and propensity for slaughter.

In either case, it is necessary for safety on the one hand, or success in seizing prey, by surprise, on the other, for the animal to have a distinct auricular perception, accompanied by a nice sense of smell. By remaining perfectly quiet, the ears are directed to and fro, as circumstances may require, to receive, most favorably and forcibly the sonorous rays, — without being obliged to move the head.* Elephants, hounds, beside an almost endless catalogue of mammalia, have pendular ears hanging down over the ear pipe, as though the design was to defend the orifice; — in these examples, the muscles are small, as they are in man, and finally, in age, for want of use, become indistinct on dissection.

Birds have but a slight rim, approaching in outline, the pinna; lizards, of which there are about forty varieties, as well as serpents and other reptiles, have nothing externally resembling an ear: in some, it is difficult, on close examination, to discover the precise spot where the nerve of the auditory machine is located. Fishes are

* It is a favorite theory with me, that an ear trumpet for deaf people, instead of being like the funnel of a common bugle, should have a broad plate grooved, and indeed, wrought in exact imitation of the external human ear, it being certain that this is the best mode of directing sound into the head, or nature would have constructed it differently.

also destitute of an external accompaniment of the inner organ, and yet all these families, including the amphibious, as frogs, turtles and the like, have a beautifully constructed internal ear, as remarkable, so far as a mechanical arrangement of parts is concerned, in conveying the pulsation of sound, as that of the most favored musician. In the sequel, it will be noticed that the common skin of their bodies, drawn as it is over the opening in the head, answers two important offices in the function of hearing.

EAR TUBE.*

When the temporal or side bone of the head, containing, entirely, the internal ear, is carefully sawed in twain, the canal, of which we are speaking, will be found about three quarters of an inch in length, and somewhat conical, being contracted towards its inner extremity—and, on an average, a little less than a quarter of an inch in diameter. This passage is a gentle curve, as the tube, from the external opening, rises upward, but at half its length, turns downward again, and there bulges out in shape, something like the bowl of a spoon. A delicate rim, like a moulding rises on the edge of this expanded mouth, for sustaining the drum head, soon to be noticed, very much like the method of nailing a hoop within the mouth of a barrel, near the chime, to keep the head from falling in. To afford greater surface, that the drum head may be considerably larger than the extremity of the tube would allow, were it stretched perpendicularly across, it is sloped, so that it requires an oval cover, under such circumstances, very much larger, than if it were round, and fitted to the square end of the pipe. All this may be examined in the temporal bone of a horse, sheep, or dog's skull, as they are found bleaching in the fields. In these animals, the analogy to the human is particularly striking. The common skin of the face is carried within the tube, for its lining, but perforated in numerous places, by the ducts of delicate little bags, lying between the bone and skin, which are constantly secreting and pouring out a bitter, nauseous oil or wax. The object of

* In books, termed the *Metus auditorius externus*,—simply meaning the external passage to the inner cavities.

this excretion is two fold, viz. first, to keep the lining moist and pliable; and secondly, to kill insects that may intrude there.* Crossing this canal, from the sides, are strong short hairs, intersecting each other in such a manner, that an insect must overcome the resistance of these pikes, or chevaux de frise, in case the wax † does not arrest its progress, before reaching the drum head, where its peregrinations are impassably limited.‡

* Ear wax, (*cerumen aurium*) is certain death to Insects that feed upon it; though its composition is such, that they cannot restrain their appetites when pent up where it is. Naturalists have taken a hint from this, to prevent the depredations of insects on dried preparations in cabinets, by washing them in some bitter decoction, as aloes or other vegetable bitters.

† At birth, the tube is filled with a viscid mucous, which, in some children, unless speedily taken away, forms a cake of hard wax, completely closing it; and by the time the articulative organs are developed, the child is actually deaf and dumb. There seems to be a peculiar predisposition to this course in some families. In others, children after having once talked, lose their hearing at four or five years of age, and become permanently deaf and dumb.

‡ When the glands are diseased, in consequence of a chronic inflammation, a thin, purulent discharge takes place, giving the individual, in some instances, trouble, inconvenience, and pain through life. I have seen a skull, in which the entire tube, on one side, was closed up by a deposition of bone. The opposite ear was partially diseased in the same manner, but the peculiar circumstances of the case, while the person was alive, could not be ascertained.

Explanation of Figure 3.

FIG. 3.

This has been an exceedingly difficult plan of the ear to execute, so as to give the exact relation of parts; — hence it is very much foreshortened.

c to d, — cc, The *meatus externus*, as it appears, taken from the bone; b, c, its two curvatures; — the first e; the second c: — dd, the oblique slant, like a spoon bowl, at the inner end, covered by the *drum head*, spoken of in the text.

e — The *membrana tympani*, stretched on its bony hoop, bulging inward.

The remaining parts, beyond the boundary of the membrane, remain to be described, particularly, although represented here for the sake of keeping up the connexion of parts in the mind.

f, g, h—The *malleus*; *f* its handle; *g* its long *handle*; *h* the head or bulb.

i, k—*incus*, or anvil; *i* short, and *k*, long processes, *m stapes*.

V, H, A, m, n, p,—The labyrinth; *n, p* the cochlea, *n* the beginning, *p* termination, *m* the vestibulum.

NOTE.—I have found immense difficulty in demonstrating this organ, without very large models:—one now in my cabinet, made of wood, magnifies the internal ear three feet, which can be seen and understood in all its relations. Formerly, when I taught anatomy at the Berkshire Medical Institution, it was customary to suppose the medical college an ear, and thus, illustrate its intricacies, by constant reference to the apartments and passage ways of that edifice.

THE DRUM, OR MEMBRANA TYMPANI. ⁽¹⁾

From the foregoing description of the *meatus* or canal, the exact locality of the drum head will be understood. Fitted to the rim of bone, in a manner similar to the parchment over the barrel of a snare drum,—it is kept perfectly tense, but by an arrangement of fibres peculiar to its organization, which is not clearly comprehended by anatomists. It is oval in shape, and somewhat concave outwardly, and so transparent and thin, that objects can be seen through it, being of the color of white oiled paper; any person of common ingenuity, can dissect this beautiful membrane in the head of a dead fowl, in five minutes, with the point of a knife. It then presents a striking resemblance to a battledoor. This closes up the extremity of the tube, in a healthy ear; notwithstanding, it is frequently ruptured by the firing of heavy guns, inflammation, and other accidents, without producing deafness. Across this drum, a fine thread of a nerve is drawn, called *corda tympani*, which gives it the requisite sensibility and connexion with the system of sensation.

(1) Lobsters, crabs, and in fact, all that remarkable class of animals, whose skeletons are outside of the body, in the form of a shell, have their ears placed at the extremities of projecting points. The lobster's can be detected at the end of a short stump, near the root of the long feelers—it consists of a perforated bony papilla, having a membrane stretched over it, —covering a drop of fluid, in which floats the auditory nerve.

When a pin-head is introduced far enough to touch the drum head, an exquisitely acute pain is the consequence, from pressing the nerve.

I have seen men with the membranes ruptured on both sides, which was inferred from the fact, that in smoking, they puffed the fumes, for amusement, out at their ears, — yet the sense of hearing, in them, did not appear impaired. The rationale of this will be subsequently explained. The deafness of old people might in some instances be alleviated by puncturing the membrane, which, by age, has become thickened and inelastic. A distinguished surgeon in England, but a few years since, discovered that by making an opening through the drum head, in peculiar cases, restored the diseased ear, *instantly*: the same operation is now successfully practised in this city.

No one can be in doubt as respects the office of this membrane: it receives the sonorous rays — having a broad surface, and being on the stretch, is put in vibratory motion by the slightest pulsations in the air, — which it transmits to the still more important apparatus within.

We have remarked that reptiles and fishes have no discernible external orifice: — the external surface appears smooth, as though they were destitute of this valuable sense. Under the skin, however, and in the bone answering to the temporal one in man, there is a round hole, — growing larger within. This cavity is the tympanum or drum barrel — answering to the apartment beyond the drum head, in men and quadrupeds, next to be elucidated. The common skin, which is thus drawn over the mouth of the tympanum, acts precisely as the drum head does, — vibrating to the least noise, with exceeding nicety. In the economy of reptiles — those scavengers of the earth, created to wallow in filth — at the threshold of organic life, an external ear or opening, would be soon destroyed, by being filled with mud, gravel or insects. The skin over the frog's ear and the camelion, is very dense, shining and tremulous. Frogs, particularly, have a splendid circular piece of skin over the tympanum, just back of their large prominent eyes.

There is a necessity for uncommon delicacy, in their case, as their ear is constructed for hearing with equal precision in water as well as air. ⁽²⁾

INTERNAL EAR.

All parts beyond the drum head are collectively called the *labyrinth*, in consequence, probably, of their intricacy.

To understand the arrangement of the apartments to which the reader is now to be introduced, requires patience, as well as close observation, or the mechanism cannot be comprehended. First the

TYMPANUM.

Directly beyond the membrane is a small room, of the capacity of a common white bean. Its name is derived from a word, meaning a drum, as it is one in office, but having, instead of one head like the kettle or two as in the snare drum, it has three heads; — the largest of which is towards the outer ear, — while at the other end of the barrel, are two little ones.

This labyrinth constitutes the difficulty in studying the anatomy of this part of the system. Three distinct

(2) In that class of serpents which is covered with scales, the external contrivance of a tense skin over the internal ear, is far inferior to the frog or lizard's: — to the underside of a cluster of thin scales, wedged in the loose dermoid texture, a slender bone, in figure like the pestle of a mortar, runs into the tube, towards the brain, and plays into the fenestra ovalis.

All the varieties of serpents are distinguished for their delicacy in the perception of sound. The *boa* family, particularly, are those which exhibit the most satisfaction in music. The writer has carefully examined a *boa constrictor*, which when fully grown, is horribly to the sight, that was inattentive to sounds, except when hungry. At such times, the scratch of a pin against the wall, roused the monster to unceasing watchfulness. The ear of the land tortoise, and the rattlesnake, both of which are in my collection, do not differ as much as the physiologist might at first suppose — though in the water turtle, constituted for hearing alternately in air and water, there is a perceptible difference. In the first, a single bone is found; while in the latter, in addition to the bone, there are fine chalky particles, which move against each other, to propagate the motion or noise in the water, to the ear containing the ramifications of the nerve.

apartments, or rooms, one beyond the other, which, in anatomical works, have further minute subdivisions, collectively, make up the labyrinth. — First, the *tympanum*, just adverted to; Secondly, the *vestibule*; and thirdly, the *conchlea*. In connexion with these are certain tubes, having sundry barbarous, unintelligible names, which are not remembered by one physician in a hundred, nor, indeed, is it at all necessary. Though retained in modern books of science, modern authors do not seem to have the courage to discard them.

Behind the ear, a hard knob of bone may be felt, with the finger, (mastoid process) on which that muscle is fastened, which, with its fellow on the opposite side, brings the head forward, as in bowing: within, this knob is hollow — being full of conical cells, resembling the spokes of a wheel, growing smaller as they unite in one pipe, which opens into the tympanum or drum barrel. Physiologists agree that the use of these cells is for reverberating sound, that it may gain strength by being reflected from wall to wall, in order to excite a stronger sensation when conveyed to the nerve: these are particularly large in some animals.* A similar piece of mechanism is discoverable in the cheek bones, and even the centre bone of the skull, for reverberating and strengthening the voice. Lions, have large cavities in the bones of their heads and faces, on purpose to increase the intensity of the vibrations; — hence their characteristic roar.

In another direction, is the minute orifice of a cone-shaped pipe, *eustachian tube*, that opens with a trumpet like extremity in the mouth, — it being necessary to the free vibration of the drum head, that the same quality of air that transmits the sonorous pulsations, should also

* In a recent letter from the venerable Dr James Thacher, of Plymouth, the following curious fact is related:

'*Reflection of Sound.*' — 'A gentleman told me, today, (May 3d, 1831,) that a few days since, he was passing through one of our streets, where there were considerable intervals between the houses, — a gentleman totally blind, walking with him, assured him that he knew exactly when he was passing a building, by a peculiar sensation in his ears, occasioned by a different concussion of the air.'

exist on the opposite side, within the barrel : the use of the eustachian tube (so called from Eustachias, the discoverer) is to admit it. Nothing, therefore, is more completely an imitation of the tympanum of the ear, than the martial drum, which has a little hole in the side, equivalent to this we are describing, descending to the mouth, the nearest point from which atmospheric air could be taken, without disarranging or disturbing the functions of vital organs. By closing the sounding hole of the drum, the music is less audible—sounding, when the air inside becomes rarefied, like music in a well. The reason is, the equal balance of air is destroyed :—such is the object and office of the eustachian tube. Sometimes, in violent sneezing, or sudden cough, the patulous mouths get stopped for an instant with saliva ; and many readers are probably familiar with the sensation of fulness that ensues, — giddiness and ringing in the ears, to the annihilation of accurate auricular perceptions, till the cause is removed. In bathing, it is not unusual to get, as it is quaintly called, a bubble in the ear, — producing these characteristic symptoms. (3)

There are many existing cases of deafness, having their origin in some such cause : the pipe finally inflames, and becomes permanently sealed : a skilful aurist, under such circumstances, will adroitly puncture the drum head, with an instrument purposely constructed and relieve the patient, without pain.

FENESTRA OVALIS.

Fenestra Ovalis means an oval window covered by one of the two little drum heads. Beyond this, supposing a person could pass through, he would arrive in the vesti-

(3) Notwithstanding the fine arguments of medical writers to the contrary, I believe that partially deaf persons hear better when the mouth is open ; instinctively, it may be observed, such individuals listen with an open mouth. The pulsations of sound thus enter the tympanum and set the fenestra ovalis vibrating, — but very much less forcibly than through the external opening, in its healthful condition.

bule, or second room. Lower down, but a few lines from this, is the second little parchment head, called

FENESTRA ROTUNDA.

This is a round window; were it possible to tear it away, and creep through the frame, the traveller would enter into one of the canals of the cochlea.

FIG. 4.

Explanation of Figure 4.

In this diagram, the labyrinth and little bones of the ear, are magnified exceedingly. This is to show the manner in which they are connected, and the order in which they are placed.

a to e—The *malleus*, about to be described; *a* a long process; *b*, a shorter one; *c*, the handle, attached to the drum head; *d*, the neck; and *e* the head of the malleus, like a mallet.

f to i—The *incus*; *f* its body; *g* its short leg; *i* the point united to the *stapes*.

k to n—The *stapes*; *k* its small head, *i* the anterior leg, *n* the basis connected with the membrane which closes the *fenestra ovalis*.

o to m—The labyrinth; *o-r*, the first turn of the *cochlea*; *s t u v*, the second; *w x*, the half or third turn; *y* the *foramen rotundum* or round window; *z z*, the vestibulum; A B C D, *superior semicircular canals*, A the *ampulla*; B C, its *curvatura*; D, its union with the inferior or posterior canal; E F G H, *inferior canal*; E, its *ampulla*; F G H, its curious curve and its junction with the first; I K L M, the *exterior canal*; I, the *ampulla*; K L, the direction of its curve; M, its termination in the vestibule.

FIG. 5.

Explanation of Figure 5.

In this, the bony case of the labyrinth, has had one half cut away to exhibit the interior.

a to l—The upper part of the cochlea; *aa*, the thickness of its external shell in a fœtus of eight months; *bcd*, the lamina spiralis; *bc*, scala vestibuli; *efghi*, the scala tympani. Here is seen the bony lamina spiralis; *b* its origin; *d* its termination in a little hook, termed *hamulus*: *k* the opening of the infundibulum, where the scalæ communicate; *l* the opening of the aqueduct, or drain of the fluids from the cochlea.

m to g—The under half of the vestibulum; *m* the thickness of its case in the fœtus; *n* the fovea or round pit; *o* an oval pit; *p* a ridge between them; *q* opening of the aquæductus vestibuli.

r, g, k, l—The canals divided; *r* the thickness of their case in the infant; *g* the posterior; *l* exterior semicircular canal; 1 opening of the big end of the posterior canal; 2 opening of the large end of the superior; 3 the opening common to their united tubes; 4 the larger end; 5 the contracted opening of the external canal.

OSSICULA AUDITUS.

Perhaps there is no insulated portion of an animal, that more clearly and satisfactorily evinces superhuman design, than the figure and articulations of the four ear

bones, which we shall now endeavor to describe. The technical phrase, *ossicula auditus*, in the Latin language, implies *little bones of the ear*. They are by far the smallest in the body. The first, in the order of their distribution is the *malleus* or mallet, — having a faint resemblance to that instrument, inasmuch as there is a long handle joined to a round knob. Secondly, the *inchus*, from its resemblance to an ovil: — *os orbiculare* or round bone, the least in size that has ever been discovered or probably exists in any terrestrial creature, — being in man considerably smaller than the smallest mustard seed. And lastly, the stapes — or stirrup, almost a miniature fac simile of a saddle stirrup. — Birds have but two of these, — of which the malleus is most developed. Turtles, of which I have a specimen, have but one, the malleus; and reptiles, as far as personal dissection warrants, have but two. In these classes, there is a departure in form, from those we are contemplating in our own species.

Explanation of Fig. 6.

FIG. 6.

There are presented here, a magnified view of the ear bones. The *os orbiculare*, or round bone, is not represented, being considered by some anatomists as only an appendage of the malleus.

The *malleus* known by its long arms: *a*, *b*, *c*, *d*, *e*, mark the same points as in Figure 4. The *inchus*, resembling a molar tooth, having shorter arms, is in the same position as in Figure 4, the letters have the same reference. The *star* points out the articulating surface for the malleus.

Any person, from the foregoing remarks, can recognise the stapes, by its shape — *a b* its head; *c* the neck; *d* anterior *erus*; *e* the second; *f* the easis.

The fourth drawing represents another view of the stapes, seen from above — *a* its cartilage; *b* anterior; *c* posterior; *d* the basis.

As these bones are placed in the drum barrel, one joined to the extremity of the other, they make a compound lever, — the object of which is, to have the freest and longest extent of motion, in a little space, — unlike the muster drum, which is continually referred to on account of familiar illustration, the sticks of this are fixed on the inside, — and though no hands are there to beat them on the head, they are connected to little cords, which jerk them down with a sort of conscious independence, whenever there is the least noise abroad, to give the brain intelligence as it were of what is going on without. ⁽⁴⁾

Explanation of Figure 7.

FIG. 7.

In this drawing, the little bones are represented of their natural size.

There is some resemblance in the motion to be effected by this chain of bones, to the up and down motion of the hand at the extremity of the arm, viz. — carrying one end of the lever through considerable space, while the other, to which the power is applied, has no perceptible motion.

(4) There are some diseases, familiar to medical gentlemen, beside local affections of the ear, which fix upon the bones, particularly about the face. Under such circumstances, a sanious discharge washes these little bones entirely away — nothing is more certain, than this fact, that the three first bones may be corroded and floated from their connexions — indeed, extracted with forceps, and the patient hears, to all intents and purposes, nearly if not quite as well as he did before. Thus the membrane, (drum head) and three out of four bones are unnecessary, it seems, in the auditory apparatus of man. Stripped thus, it falls before the frog's — being deficient in an external covering or vibrating membrane. The current or vibrations, in this case, act directly on the foot piece of the stapes — which is broad enough to offer a resistance to the sonorous column. Being connected with the membrane of the *fenestra ovalis*, it produces a motion in it, and that is propagated to the fluid beyond, and thus the nerve becomes agitated. If the stapes could be detached without rupturing the membrane of the *fenestra ovalis*, then hearing could be effected independent of the little bones. Their use is merely to strengthen the vibrations within, just in the proportion that they have a tendency to become faint, as the distance increases whence they had their origin.

Small as the ossicula auditus are, the first and last of the series have muscles, called *tensors*, *laxators*, &c, which are susceptible of demonstration. Rough points and projections on the inside of the tympanum, give attachment both to the muscles and the bones themselves. Even these minute points, the old anatomists have belabored with what they supposed significant names. One end of the malleus, the handle, is connected with the inside of the membrana tympani; the other is fitted into a socket of the inchus — and that articulated with the orbiculare or round bone, — which stands as a medium of connexion between the stapes or stirrup.

Now such is the mechanical adaptation of one of these bones to the other, that if the extreme point of the handle of the malleus which, as before remarked, is joined to the membrane, be moved the millionth or ten millionth part of an inch,² by the vibrations of the drum head, it will so operate on the inchus and then on the stapes, through the intervention of the orbiculare, that the last bone, will move through treble the space, by a single sonorous pulsation of the malleus, in the same period of time. In fact, the stirrup, in plain language, is exactly fitted into the oval window, like the box of a pump, so that a motion given to the handle of the malleus, operates on the chain, to effect the stapes, that it may work backward and forward, with the same motion and on the same principle of the working of the piston of a syringe. *To hear*, it is necessary that the stapes, attached to the parchment window, should move to and fro, for a reason hereafter to be explained, or no sensation can be conveyed by the acoustic nerve to the brain.

Gentlemen curious in these inquiries, can readily pick out the ossicula auditus from the dry skulls of horses, sheep, dogs and cats. There is a slight variation however in form, and ultimately, in burrowing animals, a wide departure in configuration from those in man.

VESTIBULE.

This word, implies a porch or entry, — being an intermediate apartment between the tympanum and cochlea; in the sense in which it is now received, it is a

hall or *porch* of the edifice beyond,—from which doors are opening into various winding passages. Its length and diameter are not far from a grain of wheat,—as in a preceding paragraph, if we suppose an individual has torn away the stapes from the little drum head, stretched across the oval window, and then cut away the latter, to wend his way into the vestibule, he will find it a long, but narrow room. ⁽⁵⁾

On one side he will discover three holes, and on the opposite, only two, which are the openings or communication of the semicircular canals, with the vestibule. Within this vestibule, are two sacs, water tight, containing a clear aqueous fluid. Though there is no communication between the sacs, the quality of the fluids distending them, is alike—one is considerably larger than the other, and both together, would not equal in bulk, two good sized pin-heads. The one of the greatest magnitude, is called the *alveus communis* or the union of rivers—from the circumstance that the canals were thought by the old anatomists to resemble streams of water, having a free communication with the water in the reservoir. *Saculus Cochlea*, the lesser one, though separated from the other by the thickness of its own and the other's walls, is eked out into a long gyrating tube, that traverses the cochlea.

This large sac, *alveus communis*, is the elementary one found in polipi—and it is this that is built upon from one species to another, till the complicated machinery of the human ear, on dissection, displays it, as the corner stone of the sense of hearing from worms, to the perfect musical ear of man.

(5) If, by any circumstance, the membrane of the *oval window* or *fenestra ovalis*, be ruptured, the fluid of the labyrinth will certainly escape. This constitutes incurable deafness. No operation, no prescription can avail, as, in the constitution of things, the acoustic nerve cannot be acted upon in any other way, than that through the agitation of the fluid which surrounds it. Dr Darwin was of an opinion that if a deaf person dreamed of hearing, the internal parts, essential to the function, were unimpaired. The same remark is applicable to the blind. I have invariably found that the incurably deaf as well as incurably blind, never dream of hearing or seeing. This clearly shows a destruction of the sense, inasmuch as the imagination cannot rouse a single vestige of their former activity.

Besides the sacs themselves, the porch is lined with a membrane of exquisite texture, in which is conducted the blood vessels that administer the blood to the contained saculi, and also secrete their contained fluid, *aqua labyrinthæ* or water of the labyrinth, further to be commented upon.

SEMICIRCULAR CANALS.

These are properly a prolongation of the vestibule—the design evidently being to furnish surface for expanding the auditory nerve, without carrying it onward towards organs that would be affected by their presence. No way could be devised, possibly, more strictly economical, than to have a circular or semicircular canal,—curving in a little space, as in a very small solid bit of bone. Precisely on this plan, are these canals—they are three in number. Let it be remembered in this place, that the tympanum, including the vestibule, little bones and semicircular canals, exclusively make up the ear of fishes, and reptiles—neither of these tribes have an external ear, nor the cochlea, which still remains to be elucidated.

So much is necessary to the true perception of simple sounds: the cartilaginous fishes, (sharks, eels, &c,) have them, and are therefore capable of judging of the direction and condition of different sounds. The Chinese drive fish from the crevices of rocks to the angling ground, by beating a gong. Pike and carp, reared in artificially stocked ponds, both in Poland and France, have been taught to come to a particular spot or border, to feed, at the ringing of a bell. Serpents, abundant evidence substantiates, are exceedingly excited by the lively strains of music—coiling themselves into a variety of folds, and giving a tremulous vibration to the tail, which long experience proves to be the result of a pleasurable sensation, and not one of displeasure, rage or pain. Egypt, of all countries on the globe, is the paradise of serpent charmers, who never fail to astonish Europeans by their tact in discovering the true characters and instinctive propensities of the individuals constituting their serpentine exhibitions.

Two of these canals, as they wind towards the side of the vestibule, coalesce—and when they perforate the wall, have only one orifice in common. The third enters alone, and this explains the two holes seen on one side of the vestibule; on the opposite side are three holes, being the orifices of the same three canals, opening singly. When the semi-circular canals are closely examined, they are observed to be larger at one extremity, near the walls of the vestibule, than at the other, the bulbs or bulges are termed *ampullulæ* or bottle shaped. A crook-neck squash is an exact, though greatly magnified representation of any one of the semi-circular canals. The diameter of the circle of which they are a little more than two thirds of a segment, varies but little from one quarter of an inch in man; and the calibre of the canals themselves will scarcely admit the introduction of a fine bristle. A probable reason for the swelling out of the *ampullulæ* will be given when discoursing particularly on the nerve.

FIG. 8.

Explanation of Figure 8.

In this enlarged diagram of the labyrinth which is laid open, the soft parts are seen. Some of my readers, particularly young

gentlemen pursuing medical studies, will derive the most profit from this plan.

a to c— The *lamina spiralis* viewed from above. The distribution of the nerve will not be easily distinguished I fear— *a a a*, the first turn; *b b*, second turn; *c d e*, the third turn of the lamina; *d e*, where the *scalæ* communicate.

Comparetti has described, so says Mr Abernethy, in Rees' Cyclopædia, the lamina to consist of four different substances, or zones: 1, the bony zone; 2, coriaceous; 3, vesicula; 4, the membranous zone.

f, *sacculus sphericus*; *g*, space between that and the *alveus communis*; *h*, *alveus communis*; *1 k i 3*, posterior canal; *1 i*, its ampulla; *k*, the nerve expanded over it; *2 l m*, the superior canal; *l*, the ampullulæ; *4 n 5*, the exterior canal, communicating at both ends with the *alveus communis*.

Within these bony tubes, are membranous ones,—prolongations of the sacs found in the vestibule; but they are not in contact with the walls: on the contrary, they are kept from them by the interposition of a fluid, whose equal pressure keeps them exactly in the centre. Further to show the exceedingly minute structure of this accurately operating instrument, it is necessary to remember that the membranous tube, being already a wheel within a wheel, is also distended with a transparent watery liquor. Still smaller canals, running through the petrous portion of the temporal bone, in which the internal ear is located, pour in and discharge the old fluid, as an unceasing process.

COCHLEA.

The third and last anatomical division of the internal ear, is the *cochlea*, or snail shell. Recollecting how the canal of a snail shell winds about a central pillar, will enable the reader to understand the text. In the snail shell of the ear, however, there are two canals, side by side, which wind twice and a half round a central pillar,—which is a hollow pillar and termed *modiolus*. At the apex, the two canals open in one common cavity, but a thin slip of bone caps over both openings as well as over the top of the hollow end of the pillar, like a parasol. This is the *cupola*, in technical language. The upper end of the hollow pillar is broad, but becoming narrower, hence it is denominated the *infundibulum* or tunnel shaped extremity. Most writers on this subject describe two pillars, as constituting the centre, but it is unneces-

sary minutiae. After leaving the inner extremity of the vestibule, commences one canal of the cochlea, which becomes smaller and smaller, till it terminates under the cupola. Now, supposing the reader were travelling in this canal, he could step from the termination of the one, we are describing over the broad opening of the modiolus, shaded above by the cupola, into the mouth of the second canal. By following its turns, increasing in diameter, as he proceeds, till he has gone twice and a half round the modiolus, he would arrive at the *fenestra rotunda* or round window. This being like parchment, semi-transparent, he could look into the *tympanum* where the little bones are lodged.

Thus it is, that one canal is in reality a prolongation of the vestibule, and the other opens into the tympanum. A fluid fills the canals, which is prevented from escaping by the oval window, in the vestibule, in one direction, and by the round one at the other. In the centre of this liquor, floating, are the finely organized threads of the acoustic nerve.

Those animals having the power of combining sounds to produce song, have a cochlea, and generally, a corresponding vocal apparatus. Birds, particularly, have a cochlea, but it consists only of two tapering tubes, united at one extremity, but diverging at the other, as in man. A musical ear was once thought by physiologists, to depend exclusively on a cochlea; but common sense teaches us, and the fact is notorious, that singers as well as those who cannot sing, have ears constructed precisely alike; and therefore, the whole mystery depends on the peculiar development of the brain.

Explanation of Figure 9.

FIG. 9.

Let it be remembered by the reader, that that part of the last as well as the following diagram, which has a sort of shell like turn, is denominated the cochlea.

The object in this drawing, is to show the soft contents of the labyrinth, of their natural size and in their natural situation. All the rock like portions of the temporal bone have been broken away.

aa, the spiral plate of the *cochlea*; *b* the round sac, or sac of the cochlea; *c* alveus communis; *g* the posterior; *k* the superior, and *l* exterior semicircular canal.

THE AUDITORY NERVE.

There is no part of the intricate organ we have been explaining, more absolutely difficult to display and to fully understand, in all its relations, than the nerve of hearing, and we shall therefore avoid all laborious anatomical descriptions, and merely generalize. All the nerves originating in the brain, are reckoned from before, backward, that is, beginning with olfactories, at the nose, and ending with the tongue, or linguals.

In this order, the auditory is the seventh,—a pair precisely alike on the two sides of the brain; not much larger than cotton sewing threads; it enters the cochlea first through a sieve like orifice, on one side of a bone that projects from the inside of the skull towards the brain. This depression where the nerve enters, to travel outward, towards the external ear, is the *meatus auditorius internus*. It assumes a variety of shapes in distributing itself in the various tubes, sacs, canals and pits we have been exhibiting. At some points, many delicate threads are discoverable, side by side: at others, fibres are seen floating in the surrounding fluid, from the main trunk: at others, the nerves assumes the form of a flocculent paste, and at others, a woolly texture. The whole, distributed thus elaborately, constitutes the nerve of hearing. The sense of hearing is not confined, in a healthful condition of the organ, to any one particular part or point: the sensation is perceived in the whole at the same instant of time. The question now may arise, why was it necessary to construct such an intricate machine, if one part of it has not a higher office to sustain than another?

Economy was the object:—to pack as much as possible in the smallest space, is observable in all animal mechanism. No other kind of arrangement of cells in the small block of bone in which these are found, would or could have afforded so much surface to spread out such an extent of nerve. This then is the probable reason for semi-circular canals, the cochlea and their appendages.

MUSICAL EAR.

No question oftener arises amongst physiologists, on surveying the auditory apparatus, than this, viz. — why has one person the ear for music, when another, whose internal organ is as beautifully and nicely constructed, is totally unable to appreciate harmonious sounds? The difficulty, probably is in the peculiar development of some portion of the brain, and therefore does not arise in consequence of a defect in the original conformation of the ear. It obviously requires as delicate auricular perception to appreciate, understand and imitate articulate sounds, as it does to sing in concert. It is by no means uncommon for an individual to possess the faculty of appreciating and cultivating, the highest departments of instrumental music, and at the same time be wholly unable to sing. This is entirely owing to a defective development of the vocal organs. A perfect organization of both, in the same individual, united to that inscrutable development of brain which gives the taste for music, constitutes the most gifted performer, and such as Handel, Mozart, Beethoven, Mad. Catalina, Garcia, the wonderful Paganini, and a few others have exhibited to the highest human perfection. Another circumstance, worth remembering, in relation to the musical ear, is the following: some persons have the ear as well as the taste for music, and yet find it impossible to accompany others in a performance. This arises, probably, in most cases, in consequence of a non-agreement in the tension of the drum heads of the two ears, or a want of correspondence in the calibre of the internal tubes; hence one ear perceives sounds to be half a tone above or below the other — the same occurs in respect to the focal distance, oftentimes, of the eyes. Time rarely corrects the former, though in the latter it finally modifies the aberration. (7)

(7) Philosophers of antiquity were more conversant with the doctrine of sounds, than the moderns: the remarkable cavern, hewn in a solid rock by a celebrated tyrant, and called *Dionysius' ear*, is said to have been an exact model of the windings of the human ear. Vitruvius gives an interesting and particular account of the manner in which the Greeks contrived to augment the compass of the voice in theatres, by placing large metal vases in different parts

RINGING OF THE EARS.

A ringing noise in the ear is an indication of a diseased state of the nerve ; generally, it arises from some slight inflammation. The beating of adjacent arteries, in consequence of local inflammation of the throat, may excite the nerve, — which being incapable of transmitting any sensation but that of sound, the *ringing* is an imperfect sensation. The eye, when the optic nerve is encroached upon by inflammation of surrounding parts, or the pressure of a growing tumor, transmits the sensation of light, though the individual be in total darkness ; affections of the brain itself may remotely excite a morbid action in many or all the nerves of sense. Hence, persons dying of acute inflammatory diseases, complain of hearing loud and strange noises, although the apartment is perfectly still.

EAR-ACHE.

Perhaps the ear-ache, (otalgia) is as difficult to explain as to remedy. Very many individuals are subject to excruciating pain in the internal ear, on taking the slightest cold or from exposing themselves to a humid atmosphere ; and others seem to inherit the disease, which no application can remove. A peculiar irritability of the nerve that crosses the drum-head, (*corda tympani*) may be one cause, — the vascular covering of which, suffering from a chronic inflammation, compresses the nerve and thus produces almost intolerable agony. Defending the external opening with cotton wool, or lint, is a common and indeed, rational defence ; but the introduction of oils, spirits and the like, is often attended with pernicious consequences. Generally such cases end in deafness. Nature, to save the rest of the machine from becoming disordered, by its sympathy with the diseased member, finally destroys it, as firemen demolish

of those edifices. Mr Curtis, an aurist, in England, has recently invented a chair, with certain pipes and tambours, that enables the individual seated in it to hear, distinctly, a suppressed conversation, which may be carried on in any part of the room.

contiguous buildings, to save a town, when they can no longer master a threatening conflagration. (7)

PARTIAL DEAFNESS, FROM A COLD.

Probably, in a majority of cases, partial deafness arises from a slight inflammation of the tube opening behind the palate. In consequence of this, the balance between the air in the tympanum and mouth, is destroyed, and the regular vibratory function of the membrane is altered. A deafness in one ear generally depends on this cause. Tumors in the throat, and polipi of the nose, by pressure on the mouth of the eustachian tube, where it opens back of the soft palatine arch, may each of them be the cause of deafness. Deafness in fevers is an excellent symptom, and offers encouragement in the worst cases, because it is an evidence of a diminution of the morbid condition of the brain.

FIG. 10.

Explanations to Figure 10.

An enlarged view of the labyrinth laid open.

a, b, c,—the *cochlea*. To exhibit the *zona mollis*; the outside or bony case removed.

(7) Painful affections of the ear may be induced from habitually picking the ears, — a very pernicious practice. In India, where a class of men particularly follow the profession of cleansing ears, cut-

d, e, f, — the vestibulum.

g, to *q,* — the semicircular canals.

g, h, i, — the posterior ; *k, l, m,* the superior ; *o, p, q,* the exterior canal.

1, 2, 3 — the lamina spiralis, seen on its under surface ; *3,* the two sacs so often mentioned in this tract, in the vestibule, which, viewed in this plan, look like one.

t, u, — the membranous posterior canal.

v, w, x, — the superior membranous canal, uniting with the last, at *x, y, z,* the exterior membranous canal.

This diagram exhibits the distribution of the *acoustic nerve* in the labyrinth ; the large branch goes to the cochlea, and the three others, smaller, to the vestibule, and three semicircular canals.

PERMANENT DEAFNESS.

A total deafness implies a destruction of the organ : but I apprehend there are only a very few persons in this condition. Even in those unfortunate fellow-beings who are *deaf and dumb*, the faculty of hearing, to a certain extent, still exists. They hear the report of a cannon, or heavy thunder, which act so powerfully on the body as to rouse the sleeping energies of the acoustic nerve. In fact, the tremor is communicated by being propagated through the bones of the head. Fishes, of the bony kind, have the organ of hearing acted upon in the same manner, as the nerve is completely cased up in solid bone, without either drum-head or external openings. Many years ago, in the course of a visit at the Hartford deaf and dumb Asylum, I ascertained many of the pupils could *feel* sounds, which they could not hear, by holding a twine between the teeth, while the other end was tied to a musical instrument at considerable distance. One young gentlemen assured me that he derived a pleasurable sensation from the vibrations of the strings of a piano. It is my firm belief that many persons who

ting the nails, &c — though in that climate the secretions may be fluid, in greater abundance, and discharge freely, the plucking of the hairs and frequent introduction of *scraping* instruments render the organ irritable, and less accurate in the perception of sounds.

Tumors, ulcerations and other troublesome complaints are brought on by picking them. A sudden pressure on the *corda tympani*, a nerve belonging to the face, which crosses the drum-head, by the head of a pin, may forever after render it liable to inflame on the slightest exposure.

Fluids ought not to be poured into the external ear to *drown* insects, as the worst consequences may ensue.

are deaf and dumb, might readily be restored by a puncture of the membrane, even in advanced life. ⁽⁹⁾

CONCLUSION.

None of the organs of sense are more complicated or splendidly constructed than the one under consideration. The will has it but slightly under its control, and being unable '*to withdraw itself from impressions,*' it has the curious apparatus of little bones to increase or diminish the intensity of impressions on the nerve, like a regulator between the external agent and the nervous tissues. Judgment, by the combined assistance of the other senses, perfects the function of the organ — and ideas, without number are constantly ushered into being by the sense of hearing.

By this sense, music is a never failing source of pleasure, heightened and infinitely modified, according to the physical development of the ear, and the discipline and education to which it has in modern times been subjected. 'The causes of the pleasure resulting from harmony and melody, are very far from being satisfactorily explained, notwithstanding the sagacious conjectures and repeated attempts of the most able metaphysicians, as well as physiologists: we know no more of them than we do of the causes of the pleasures and pains of all the other senses.'

(9) Dr Forster of Manchester, England, who recently ascended to the height of 6000 feet in a balloon, in company with Mr Green, the aeronaut, remarked that the pressure on the membrane of the ear, arising from the rarefaction of the atmosphere, was so painful as to oblige him to descend; sounds, however loud, below, soon became inaudible as he ascended. Dr Forster suggests that an ærial jaunt into the clouds, might cure some kinds of deafness.

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SOUND.

I. VIBRATIONS OF SOUNDING BODIES.

EVERY one has noticed that, in many cases, where sound is produced, there is a trembling or vibration of the sounding body. This is evidently the case when a heavy bell is struck, or the large strings of a viol are sounded. In some other cases, as in the flute and whistle, these tremblings are less obvious. They are not however less real. Sound is, in all cases, produced by *vibrations in a sounding body, occasioning similar vibrations in the air.*

Various facts will, at once, occur to the reader, illustrative of this principle.

The vibrations of a large bell, or of a viol string, as above remarked, are *visible*.

The head of a drum is thrown into a state of vibration by the strokes of the drumstick.

If a tuning fork, when sounding, is touched to the teeth, the vibrations are sensibly felt.

If the tuning fork or a bell be touched with the finger, so as to check these vibrations, the sound is instantly stopped.

In the *reed stops*, as they are called, of an organ, the sounds are produced by the vibrations of thin slips of metal, fastened at one end.

If a large glass vessel, partly filled with water, is made to sound by rubbing the edge with a wet finger, the vibrations produced are made evident by peculiar and beautiful undulations in the water. If the upper part of the

tumbler is held by the hand, so as to prevent vibrations, the sound will be prevented.

Sound may be produced by one single shock or concussion of the sounding body, in which case the vibrations continue but an instant. The blow of a hammer, the crack of a whip, a pistol shot, the stroke of a bell, when the hand is pressed upon the outside of the bell, so as to prevent a continuance of the sound are examples.

If, however, these vibrations are continued for some time with regularity, a continued and equable sound is produced, called a musical sound or tone. Arnott illustrates this subject in the following manner. 'If a wheel with teeth be made to turn and to strike a piece of quill with every tooth, it will, when moved slowly, allow every tooth to be seen, and every blow to be separately heard; but with increasing velocity, the eye will lose sight of the teeth, and the ear will at last hear only a smooth continued sound, called a tone, of which the character will change with the velocity of the wheel.'

In like manner, the vibrations of a long harp-string, while it is very slack, are separately visible, and the pulses, produced by it in the air, are separately audible; but as it is gradually tightened, its vibrations quicken, and the eye soon sees that it is moving only by a broad shadowy line; the distinct sounds which the ear lately perceived, run together, owing to the shortness of intervals, and are felt as one uniform, continued tone, which constitutes the note or sound proper to the string. It is the elasticity of such a string which causes the repetition of the percussions, and therefore the continuance of the sound. Thus the string having been pulled at its middle to one side, and then let go, its elasticity carries it back quickly to the straight position; but by the time it has reached this, it has acquired a momentum which, like the momentum of a vibrating pendulum, carries it nearly as far beyond the middle station as the place from whence it came. It has to return therefore from this second deviation, by its elasticity, in the same way; but still passing the middle as before, it has again to return, and thus continues vibrating as a pendulum does, until

the resistance of the air and friction bring it gradually to rest.

A large vibration of any one string occupies very nearly the same time as a smaller, because the more the string is bent, the more forcibly it is pulled back again by its elasticity; hence the uniformity of a musical tone.

To the perfection of a tone, it is of no consequence in what way the pulses are produced, provided they follow with sufficient regularity; witness the pure sound produced by the motion of a fly's wing — supposed by many to be the *voice* of the insect. The clacking of a corn-mill, and the noise of a stick, pulled along a grating, are not musical only because the pulses follow too slowly.

Where a continued sound is produced by impulses which do not, like those of an elastic body, follow in regular succession, the effect ceases to be a clear, uniform sound or tone, and is called a *noise*. Such is the sound of a saw or grindstone; the roar of waves, breaking on a rocky shore, or of a violent wind in a forest; the roar and crackling of houses, or of a wood in flames; the mixed voices of a talking multitude; the diversified sounds of a great city, including the rattling of wheels, the clanking of hammers, the voice of street criers, the noises of manufactories, &c; which rough elements, however, at last mingle with such uniformity, that the combined result is often called the hum of men, from analogy to the smooth mingling miniature sounds which constitute the hum of a bee-hive.

II. VIBRATIONS IN THE AIR.

The vibrations of sounding bodies above described are communicated to the air around them, and thence to the ear. Without the air, therefore, although the bell would vibrate if struck, the vibrations would not be communicated to us, and we should hear no sound. That these vibrations are thus conveyed through the air is evident from a variety of facts and experiments. The following is, however, a sufficient illustration.

If two bass-viols, tuned so that corresponding strings in each, will give the same sound, be placed in two rooms,

at a distance from each other of ten or fifteen feet, and the bow be drawn across a string of one, so as to produce a loud sound, the corresponding string in the other instrument will be thrown into vibrations, and a similar sound will proceed from it. This can arise from no other circumstance than that the vibrations of the string, across which the bow is drawn, are communicated to the air, and through the air to the same string in the other viol.

These *vibratory* motions in the air, are very different in their nature from *progressive* motions, and it is important here to explain them. They are usually illustrated by the undulations of water.

If a piece of wood is lying still, on the surface of water, and a stone be thrown beyond it, a series of undulations are produced, which recede from the place where the stone fell, and *seem* to be a motion of the water itself towards the shore. This is, however, not the fact. The motion seems to be progressive, but is really only vibratory. The stone falling into the water, produces a depression in that place, the surrounding water presses in to fill it, and by its momentum an elevation is produced. The water thus elevated falls by its weight, and produces an elevated ring around it. This by its descent produces another and another, larger in diameter, and nearer the shore; but in such rapid succession, that it seems as if *the wave first produced, itself moved towards the shore*. That this is not really the case is evident from this fact: If, before the stone was thrown in, a piece of wood had been floating on the water, we should have observed that the wood would approach but very little, if at all, nearer the shore. It would *rise and fall* with each successive circle, but still make no visible progress. Now, as the wood would move with the water, if there was really a progressive motion of the latter, we can safely infer that all the motion of the water is simply a rising and falling, or a *vibratory* motion, not a *progressive* one, towards the shore. The appearance is delusive.

The undulations of the air are in the same manner vibratory, that is *to and fro*, not progressive. This may be illustrated by the annexed diagram.

Let A B C D, represent the strings of two bass-viol, placed fifteen or twenty feet distant; $o x y z$, particles of air through which the sound made by drawing a bow over the string A B, of the first viol, is communicated to the string C D, of the second viol. When the string A B, is put in motion it comes in contact with the particle of air o , or sufficiently near to give it an impulse. This particle receives an impulse sufficient to carry it forward in the direction of the dotted line e , from thence it returns an equal distance on the other side of the point from whence it started.

The second particle of air, x is impelled forward in a direction towards y , by the first particle o , and the same with all the others of the series. The sound made by drawing a bow over the string A B, of the first viol, is thus transmitted through the successive particles of air, and at length reaches the string C D of the second viol, and causes it to sound. Here it will be evident that there is no progressive motion of the particles. Each one moves slightly and then returns to its place. It probably goes back farther than to its first place, and after various oscillations comes to a state of rest in its original position. If, however, the whole mass of air moved *onwards*, it would be *wind* not *sound*.

That sound is thus conveyed by vibrations of the air, is evident from many other facts. The concussion thus produced is sometimes very great. A discharge of artillery will sometimes break windows. The thunder has often the same effect. An explosion of a powder mill produces a shock in the air for many miles, though undoubtedly in this case the concussion is not *altogether* produced by the sound.

It follows from what has been said above, that without air there would be no sound. This fact has been proved by many experiments. If a bell be placed under a glass vessel from which the air has been exhausted, any efforts to produce a sound by striking the bell, will be in vain. A faint sound may sometimes be heard; but this would not be the case if the air could be completely exhausted from the glass vessel, and the connexion with surround-

ing solid substances, capable of conveying sound, could be entirely cut off.

This experiment has been tried in the following manner. Under the receiver of an air pump, a piece of clock work was placed, to produce sound in a bell, which rested upon a bag stuffed with cotton or wool. A vacuum was produced by working the pump, and then by means of a handle, or stem which went through the top of the receiver, the clock work was set in motion, and the hammer was then seen to strike the bell continually, but no sound was heard. Another philosopher, to render this experiment still more decisive, placed the bell in a first receiver, which remained full of air, and which was covered by a second receiver, so disposed that a vacuum might be made between the two. Although in this distribution of things, a sound was produced in the interior receiver, when motion was communicated to the hammer, yet the bell remained mute with regard to the observer; he perceived no sound.

The loudness of sounds consequently depend in some measure upon the density or rarity of the air. When the air is dense a distant bell is heard more distinctly than usual. A cannon fired on the top of a mountain is *not* heard so distinctly as it would be in a less elevated situation, on account of the rarity of the air. Sausure noticed this when upon the Alps. The pistol which he discharged at that great elevation, produced scarcely anything but a flash. In a deep mine, where the air is denser than at the surface, the sound would be louder than usual. The thundering noise, however, which travellers produce in caverns, is not owing chiefly to this cause, but to reverberations which will be subsequently explained.

Sound is affected not only by different degrees of density in the atmosphere, but it varies in the same way, when produced in different gases of various densities.

‘Sounding bodies vibrate much more rapidly, if placed in hydrogen, than in common air, and more quickly in common air, than in any of the heavier gases:—because the lighter the air, the less is the resistance to a body moving in it. Thus also a bell will

ring under water, but produce a much graver sound than in the air.

‘That water also is a vehicle of sound, is proved by the fact last mentioned, by the distinctness with which the blows of workers around a diving-bell are heard above, and by the fact that fishes hear very acutely.’*

III. MOTION OF SOUND.

1. *Communication of sound through solids.*

Sound is communicated also through solids. The vibrations move even with greater rapidity through a solid substance ; the following are examples :

‘Children often suspend a pair of tongs or other metallic substance by a string, the end of which is pressed into the ear. The sound in this case, is heard much more distinctly than usual, the vibrations being conveyed by the solid fibres of the string. In the same manner the scratch of a pin at one end of a log of wood is directly heard by the ear applied at the other end, although through the air it is not at all audible. Savages often discover the proximity of enemies, or of prey, by applying an ear to the ground and hearing their tread. The approach of horsemen at night is easily discovered in the same way. The report of a cannon placed on ice, is carried much farther by the ice than by the air around. In the military operation of mining, or cutting away under ground, for the purpose of entering a citadel, or blowing up fortifications, the approach of the enemy is often discovered by the subterranean sound of the pioneers’ tools. The awful muttering of earthquakes is merely the sound of subterranean explosions, conveyed from amazing distances, by the solid earth.

‘The readiness with which solids receive and transmit sounds, is further perceived in the fact, that a small musical box while held in the hand, is scarcely audible, but when pressed against a table or a door, will rival a little harp. The vibration communicated from the box, pervades the whole of the wood, and the extended surface then acting on the air increases the effect. The con-

* Arnott.

struction of violins, harps, guitars, &c, and of sounding boards, generally is governed by the same law. In the dancing-master's *kit* or small fiddle, which he carries in his pocket, there are the same strings, and the same bow as for a violin, but it has very little sound because the extent of its surface is so small. A heavy piece of metal, called a *sourdine*, when fixed upon the bridge of a violin, damps the sound, because it is a dead mass resisting the motion of the elastic wood.'

2. *Motion of Sound through the Air.*

Every one has noticed that sound does not pass from place to place, through the air instantaneously. We see the flash and the smoke of a distant cannon some seconds before we hear the report. When a cloud is remote from us, we see its lightning, and a pause, sometimes of minutes, intervenes, before the rumbling of the thunder reaches our ears. We see the flashes, in these cases, at the instant of their occurrence, and hear the sound after a sufficient interval has passed to allow of the transmission of the vibrations through the intervening distance.

The velocity with which sound passes through the air, has been ascertained by careful experiments. The method is obvious. If a ship stationed at a known distance from the spectator, fires a gun, and the distance between the flash and the report is accurately noted by means of a stop watch, it is easy to calculate the velocity per second. For example, suppose that by means of the stop watch, we find that thirty seconds elapse after seeing the flash, before hearing the report. We next ascertain exactly the distance of the ship. Suppose we find it to be 6 miles and 860 yards. This reduced to feet, is 34,260 ft. which divided by 30, the number of seconds, gives us for a quotient 1142. The result of the calculation therefore is, that the sound of the cannon travels at the rate of 1142 feet in a second.

This is the velocity which is now generally assigned to sound. Though different experiments have given very different results, as the following table will show. The first number, 968 feet, given by Sir Isaac Newton, was obtained not by experiment but by mathematical calculation.

	Feet.	
Sir Isaac Newton,	968	Princip Phil Nat L 2, Prop. 50.
The Hon. Mr Roberts,	1300	Phil. Trans. No 209.
The Hon. Mr Boyle,	1200	Essay of languid Motion, p 29.
Dr Walker,	1338	Phil. Trans. No 247.
Mersennus,	1474	Balistic Prop. 39.
Mr Flamstead and Dr Halley,	1142	Exper. per Acad. del. Cimen.
The Florentine Academy.	1148	P. 141.
The French Observers,	1172	Du Hamel Hist. Acad. Rex.

3. *Experiments for calculating the velocity of Sound.*

Perhaps the most careful of the experiments which have been performed, were those of Derham, not far from London. One observer ascended a hill to discharge a gun, and others took their stations upon other hills at various distances from three to twelve miles. In order to measure the time, they had a very accurate instrument, with a pendulum vibrating half seconds. That the reader may judge of the particularity and accuracy with which the experiments were performed, we subjoin the queries which the philosophers proposed to themselves, and with reference to which the arrangements of the experiments were made.

‘ 1. How much space sound passed through in a second, or any other interval of time? 2. Whether a gun discharged *towards* the observer, transmit the report in the same space of time, as when discharged the contrary way? 3. Whether, in any state of the atmosphere, when the mercury either ascends or descends in the barometer, sound pass over the same space in the same interval of time? 4. Whether sound move with greater velocity in the day-time, than in the night? 5. Whether a favorable wind accelerate sound, and a contrary wind retard it; and how winds affect sound? 6. Whether sound move with a greater velocity in a calm day, than when the wind blows? 7. Whether a violent wind blowing transversely accelerate or retard the motion of sound? 8. Whether sound have the same degree of motion in summer and winter, by day and night, in snowy and in fair weather? 9. Whether a great and small sound have the same degree of motion? 10. Whether in all *elevations* of a gun; viz. from point blank to ten, twenty, and ninety degrees,

sound reach the observer's ear in the same space of time? 11. Whether all sorts of sounds, as those of guns, bells, hammers, &c, have the same degree of motion? 12. Whether the different strength of gunpowder vary the motion of sound? 13. Whether sound pass over the same space in the same interval of time, on the tops of high mountains, and in the bottoms of valleys; or in the highest and lowest parts of the atmosphere? 14. Whether sound in acclivities and declivities have the same degree of motion; or whether it descends from the top to the foot of the hill with the same velocity, as it ascends from the foot to the top of the same? 15. Whether sound move swifter in the beginning, and slower at the end; as is the case in a great many other violent motions? 16. Or whether it be not rather equable? viz. moving in half the time, over half the space; in a fourth part of the time, a fourth part of the space, &c. 17. Whether sound have the same degree of motion in all climates, both north and south, in England, France, Italy, Germany, &c? 18. Whether sound pass from one place to another in a straight line, or in the shortest way; or whether it move along the superficies of the intermediate earth?' The answer to all these questions may be given in a single sentence. The velocity of sound *through the air*, is under all circumstances the same. A wind will of course retard or accelerate it, according to the velocity of the wind.

On account of the variation in the results of previous experiments, the French Academy of Sciences, in 1728 undertook them anew. They stationed a cannon at Monthlery, and noticed the report at Montmartre near Paris, a distance of 2 miles, 4076 feet. They found the sound to have a uniform velocity of 1107 feet in a second; so that it was merely weaker at a greater distance, but passed successively through equal spaces in equal times. The velocity seemed to be affected by no circumstances but the direction and force of the wind. It was the same in rainy as in settled weather. The wind occasioned no variation when it blew in a direction perpendicular to a line drawn from the cannon to the observer, But when both were in the same direction, it

was necessary to add the velocity of the wind to that of the sound ; when in opposite directions, this was to be subtracted. The *force* of the sound was found to cause no change in the velocity, the feeblest report reaching the ear in an equal space of time with the loudest.

The velocity of sound as determined by the French Academicians, is less by 35 feet than the commonly received computation of Derham, 1142. The Florentine Academy make it 1148. Farther experiments are necessary to determine which of these is nearest to truth ; or whether the velocity does not vary in different times, places, and temperatures. Some late philosophers have doubted the uniformity of the velocity. Yet Derham, whose experiments have been conducted with great care, says, 'That in all weathers, whether the sky be clear and serene, or cloudy and turbid, whether it snows or rains, thunders or lightens, whether hot or cold, winter or summer, whether the mercury in the barometer rises or falls, in all changes of atmosphere, *wind only excepted*, the *velocity* of sound is neither more nor less ; only the sound will be more or less loud.

As before stated, some other philosophers have supposed that they could perceive a difference in the velocity of sound, occasioned by various circumstances ; such as the state of the weather, the loudness of the sound, &c. But the experiments of Derham, which lead to a different result, were performed with greater care, and with more accurate instruments. The opinions of the other philosophers, too, might be expected to be influenced by the strong expectation which any one would have of finding such a difference. For example, every one would expect that a very loud and intense sound would force itself through the air with greater velocity than a faint and dull one. Yet the result of Mr Derham's experiments, showed that the sounds of all bodies, such as guns, bells, hammers, &c, have the same degree of velocity. 'He compared the strokes of a hammer, and the report of a gun, at the distance of a mile, (that being the greatest at which he could hear the sound of a hammer,) and he found that the sound of both reached him at the same

time; and that it had passed over $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{4}$, of the same space, in $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{4}$, of the same time. As to intense and languid sounds, Mr Derham found that they pass through the same space in the same time; as appears from the following experiments. At Tilbury Fort were fired one or two common guns, and also a great gun, into which the powder was well rammed; the report of all these reached Mr Derham, who was about three miles off, at the same time. After sun-set, some muskets, sakers,* and mortars were discharged on Blackheath. Mr Derham could not hear the muskets, either on account of the great distance, or because the air was not clear enough; yet he heard the sakers and mortars in the same space of time, though the report of the mortars was more languid and weak than that of the sakers.'

4. *Various Phenomena produced by the Motion of Sound.*

In consequence of the fact that it requires some time for sound to pass through the air, it is impossible for two sounds at any distance from each other, to be heard at the same moment of time, by persons who are at those places.

If A and B are standing at the distance of one mile from each other, and each fires a gun at the same moment, A will not hear B's gun until several seconds after he hears his own, because the sound will require that time to pass through the distance between them. And the same will be the case with B. One might at first suppose that if A should wait and fire at the moment he hears the report from B the two sounds would then be heard together. A would hear them together, but the time that must elapse after B had fired, before the sound from A would come to *him*, would be greater than if they fired at the same moment. For he must wait till the sound of his own gun had gone to A, and then until the sound of A's discharge should return to him. It is thus evidently impossible for two persons, standing at a distance from each other, to produce a sound which shall be heard by both, at the same time.

* A species of ordnance.

It is on account of this principle, that in long ranks of soldiers where two bands of music are placed at a considerable interval from each other, it is impossible for the two bands to keep time with each other. They may indeed play together, but each soldier will hear the nearest sounds quickest, and thus they will seem to be out of time. It is often noticed too, that if from an eminence we look upon a long column which is marching to a band of music in front, the various ranks do not step exactly together. Those in the rear are in each step a little later than those before them. This produces a sort of undulation in the whole column, which is difficult to describe but which all who have noticed it will understand. Each rank steps, not when the sound is *made*, but when in its progress down the column at the rate of 1142 feet per second, it reaches their ears. Those who are near the music hear it as soon as it is produced, while the others must wait till sufficient time shall have elapsed, for it to have passed through the air to them.

Should a commander stand at the distance of a fifth of a mile from his army, and command them to fire, they might all obey at the moment when the word of command reaches them ; but the officer will hear the report of the guns from those at the side nearest him first, then those a little farther off, and so on to the most remote. Thus though all might obey with equal alacrity, the sounds will not, and cannot appear simultaneous, for the reports of the distant guns must be delayed long enough for the command to pass from the officer to the men, and then for the sound to return. All attempts therefore to make the firing appear exactly simultaneous from a long line must be in vain.

5. *Distances calculated by the velocity of Sound.*

The velocity of sound being thus once ascertained, it is evidently easy to calculate with the assistance of this knowledge, the distance of any object near which a loud sound is produced, as a ship firing a gun at sea, or a thunder cloud.

In order to illustrate this subject, let us suppose ourselves standing on an elevated rock near the sea-shore; a cannon is fired from a distant ship, and we are desirous to know the number of miles the ship is below us. We observe the moment when we see the flash of the cannon, and then by a stop watch or by some accurate instrument count the number of seconds which elapse before we hear the report. Suppose it to be 30 seconds. Now, as it has been ascertained, that sound travels at the rate of 1142 feet in a second, we must in this case, multiply 1142 by 30. We shall thus find that the ship is 34,260 feet from us. Dividing 34,260 by 5280 (the number of feet in a mile,) we find that the ship is six miles and 2580 feet from us.

It is evident that these calculations of distances cannot, in any case, be very accurate. It is difficult to ascertain the time within half a second, and in half a second the sound would move five hundred feet. But it may be of some service occasionally to know the distance of an object within a thousand feet. If chased at sea by a pirate, it would be a satisfaction to know that his ship is many miles from it, even if we were not sure whether it was seven miles or seven and a half. In a thunder storm, also, perfect accuracy in regard to the distance of the cloud is not necessary. In the same manner, the distance of a thunder cloud in a storm, may be easily calculated by noticing the time which elapses between the lightning and the thunder. It will be recollected by our readers, that every flash of lightning is attended by a clap of thunder; and that they both really take place at the same instant, though we see the flash usually at the moment it occurs,* while we must wait for the sound of the thunder to traverse the intermediate distance. In case a stop watch is not at hand, the distance may be calculated with some success, by counting the pulsations of any healthy individual. These pulsations are generally about once a second.

* Light travels a great distance almost instantaneously, it requiring only 8 seconds to cross the orbit of the earth, a distance of 190,000,000 of miles. Consequently in a passage of a *few miles*, the lapse of time is not perceptible.

IV. THE EAR.

The vibrations in the air caused by a sounding body, are communicated to the ear, and from that to the brain, by the connexion of which with the mind, the idea of sound is produced.

The ear is composed of an external ear, so contrived as to collect the vibrations of the air; of a tube lying at the root of the external ear, through which these vibrations pass to a thin membrane, called the drum of the ear, on account of its resemblance to the head of a drum. This vibrates, and gives motion to four small moveable bones, which are so connected with each other, and with the drum of the ear, that if the drum of the ear vibrate, these bones are put in motion, at the same moment. The last bone of the four, is called the stapes, which in connexion with some complicated parts whose use is not fully understood, conveys the sound to the auditory nerve which proceeds from the brain. When the vibrations thus come to the sensorium, *they there produce sound*. Strictly speaking there is no *sound*, but only a *motion of particles*, before. A thousand thunders would produce no sound unless there was a living being to hear. Without this they would occasion only silent agitations of the air.

V. REFLECTION OF SOUND, OR ECHO.

Suppose a cannon to be fired at a distance from a perpendicular wall. This causes vibrations in the air, and the particles conveying sound at length reach the wall, and not being able to proceed any further, return back, and produce what we call a *reverberation* or *echo*.

The echo may be illustrated by the following experiment. If a pebble be thrown into the centre of a vessel containing water, circular waves will be immediately formed around the place where it falls, and will gradually extend until they reach the sides of the vessel; when not being able to proceed farther, they will be reflected, as it were, and a new succession of waves will extend towards the centre. The air moves in precisely the same manner in the production of the echo.

An echo follows every sound which is made, but it generally follows the principal sound so immediately that we do not perceive it. The more distant a sound is from

the object which reflects it, the longer will the echo be in returning.

Consequently, a person speaking in a large hall, is obliged to speak more slowly than he would in a small room, in order to give the echo time to return from all parts of the building. If he neglects this, and speaks as rapidly as usual, it will be almost impossible to understand him, as the words which he utters will be confounded with the returning echo.

Remarkable Echoes.

The following are some of the most celebrated echoes, which writers have noticed.

Dr Plot, in his *Natural History of Oxfordshire*, mentions an echo in Woodstock Park, in Oxfordshire, which repeats seventeen syllables in the day-time, and twenty in the night. The difference if there is any is probably occasioned by the stillness of the night which renders the sounds more audible.

Harris describes an echo on the north side of the Shipley church, in Sussex, as repeating twentyone syllables distinctly, under favorable circumstances.

Dr Birch informs us, that there was an echo at Roseneath, in Argyleshire, in Scotland, which distinctly repeated, three times, a tune played on a trumpet. When a person, placed at a proper distance, plays eight or ten notes, they are correctly repeated, but a third lower; after a short silence, another repetition is heard, in a still lower tone; and, after another short interval, there is a third repetition, in a yet lower tone.

Addison describes an echo at the palace of Simonetta, near Milan, as returning the sound of a pistol fiftysix times. The palace has two wings; and, when a pistol is fired from a window in one of the wings, the sound is reflected from a dead wall in the other wing, and is heard from a window in the back front. The following account of it, however, from Keysler, is more minute and interesting.

‘At the Marquis Simonetta’s villa is a very extraordinary echo; it is occasioned by the reflection of the voice between the opposite parallel wings of the building, which are fiftyeight common paces from each other, and

without any windows or doors, by which the sound might be dissipated or lost. The repetition of the sound dwells chiefly on the last syllable, which might have been altered by allowing a greater distance between the two wings; but possibly it was apprehended, that the number of the repetitions would be diminished by that means. 'Two or more bodies placed opposite each other, at different distances, are requisite to form a multiplied echo; or the wall at which the speaker stands, must have another wall opposite to it, so as to form two parallel planes, which will alternately reflect to each other the sound communicated to them, with as little dissipation as possible. This last circumstance is found in the two parallel wings of this seat, which, forming right angles with the main body of the building, have a very surprising effect. A man's voice is repeated above forty times, and the report of a pistol above sixty, by this echo: but the repetition is so quick, that it is difficult to tell them, or even to mark them down, unless it be early in the morning, or in a calm still evening; when the air is rather too moist or too dry, the effect is found not to answer so well.'

Southwell mentions a building, similar to the palace of Simonetta, which had projecting wings, and produced sixty repetitions of every sound.

The Abbe Guynet describes an echo on the road from Rochepot to Chalons, which repeats, in the day-time, fourteen syllables well articulated, and, during the night, sixteen syllables.

About three leagues from Verdun, there is a singular echo, occasioned by two towers projecting from the body of a house, and distant twentysix toises, or about fifty metres. When a person stands in the line between the two towers, and pronounces a word in a pretty high tone, he will hear it repeated twelve or thirteen times at equal intervals, and always more feebly. If he places himself at a certain distance out of this line, the echo is no longer heard. One of these towers has a low apartment vaulted with hewn stone, while the other has its vestibule vaulted.

In the memoirs of the French Academy of Sciences for 1792, there is described a curious echo, at Genefay,

in the neighborhood of Rouen. A person who sings, does not hear the repetition of the echo, but merely his own voice; while those who listen hear only the repetition of the echo, though with singular variations. Sometimes the echo seems to approach, and at other times to recede. One person hears a single voice, and another several voices: one person hears the echo on the right, and another on the left; the echo always varying with the position of the person who hears it.

M. Quesnet has described another singular echo near Rouen, in the Memoirs of the Academy for 1664.

In the neighborhood of Coblentz, on the banks of the Rhine, there is a very remarkable echo, which is described by Barthius, in his notes upon the Thebaid of Statius. He has heard it repeat words seventeen times, and it produces exactly the same effects as that at Genefay, near Rouen.

At Lochencilan, a lake in Invernesshire, and the property of J. P. Grant, Esq. of Rothiemurchus, there is a very fine echo. The wall of an old castle, in the middle of the lake, repeats several syllables with great distinctness; and when a pistol is fired, the sound is repeated about thirty times, from the numerous and lofty hills with which the lake is encircled.

In the neighborhood of Edinburgh, in the King's Park, there is a place called the *Echoing Rock*. A person standing in front of this will hear repeated with great distinctness several syllables which he may utter. The sound in this case is reflected from a circular wall at no great distance, and the rock to which the property is ascribed merely happens to be near the centre of the circular wall.

In erecting the baptistry of the church of Pisa, the architect, Giovanni Pisano, disposed the concavity of the cupola in such a manner, that any noise from below is followed with a very loud and long double echo. The repetition, however, is not so distinct as that of Simonetta. Two persons whispering, and standing opposite to each other, with their faces near the wall, can converse together without being overheard by the company between. This arises from the elliptical form of the cupola, each person being placed in the focus of the ellipse.

In the Cathedral church of Gloucester, there is a whispering 'gallery above the eastern extremity of the choir, which extends from one end of the church to the other. If two persons, placed at the distance twentyfive toises, speak to one another in the lowest voice, it is distinctly heard. A similar effect is produced in the vestibule of the Observatory of Paris, and in the cupola of St Paul's in London. Mr Southwell informs us, that, in Italy, on the way to Naples, and two days' journey from Rome, he saw in an inn, a square vault, where a whisper could easily be heard at the opposite corner, but not at all on the side corner that was near to you. 'This property was common to each corner of the room. He saw another on the way from Paris to Lyons, in the porch of a common inn, which had a round vault. When any person held his mouth to the side of the wall, several persons could hear his whisper on the opposite side.

The whispering gallery in St Paul's, London, is a great curiosity. It is 140 yards in circumference. It is just below the dome, which is 430 feet in circumference. A stone seat runs round the gallery along the front of the wall. On the side directly opposite the door by which visitors enter, several yards of the seat are covered with matting, on which the visitor being seated, the man who shows the gallery whispers with the mouth near the wall, at the distance of 140 feet from the visitor, who hears his words in a loud voice, seemingly at his ear. The mere shutting of the door produces a sound like a peal of thunder rolling among the mountains. The effect is not so perfect if the visitor sits down half way between the door and matted seat, and much less if he stands near the man who speaks, but on the other side of the door.

VI. MUSICAL SOUNDS.

The smallest number of vibrations which will produce sound, is twelve and a half per second, and the greatest number audible is 6400 per second. There are two methods, both exceedingly ingenious and curious, by which these numbers are ascertained, which however, cannot here be explained.

If a person should have a bar of steel vibrating at the rate of twelve and a half times a second, a very low hum would be heard, — so low that it would scarcely be perceived that it was a sound. Then if the experimenter should have another bar of steel, so adjusted that it would vibrate, twice as fast, that is, at the rate of *twentyfive* times per second, it would evidently produce two vibrations to every one of the first bar. Thus the bars would correspond at every other vibration, and no two bars can correspond more closely.

A person might for a moment think that if one vibrates *thirteen* times, when the other vibrates *twelve and a half*, they will coincide more nearly. But in this case, they would only coincide at the thirteenth vibration, whereas if one vibrates *twentyfive*, while the other does *twelve and a half*, they correspond every *second* beat. Now it is found that the two sounds produced by two bars, vibrating one twice as fast as the other, unite more completely and more pleasantly, than any other sound; and one of these is called the octave of the other.

Fifty vibrations in a second would produce a sound an octave above the one vibrating twentyfive times, and one hundred the octave above that. The next would be 200 in a second; the next 400; then 800; then 1600; then 3200; and last 6400. This makes in all nine octaves, in which is included the whole compass of musical sound. Beyond that number the sound becomes inaudible.

These octave distances are subdivided; that is, between every two of these sounds a multitude of others may be made. The whole number of possible sounds, therefore, is immensely great, but all must be comprised between the first and last of the sounds above described. The first, produced by twelve and a half vibrations being a low hum scarcely distinguishable as a sound, and the others increasing in shrillness until the last, produced by 6400 vibrations in a second is almost lost to the ear. The human voice produces only a small portion of these possible sounds, perhaps those from one hundred to eight vibrations in a second.

SCIENTIFIC TRACTS.

NUMBER XIV.

METEORS.

THAT department of physical science which treats of atmospherical phenomena is called Meteorology. This term includes all the various phenomena of the atmosphere, as winds, clouds, rain, hail, snow, dew, thunder, lightning, and the fiery meteors.

The word Meteors is almost exclusively confined to those luminous bodies, which occasionally appear in the sky, and which are not governed by any known laws. They may be arranged in three general classes. I. *Aurora Borealis*, or Northern Lights. II. Shooting Stars. III. *Ignes Fatui*, usually termed Will o' the Wisps, or Jack o' Lanterns.

I. *Aurora Borealis*. — When walking in a cloudless evening, the eye is frequently directed to luminous appearances in the northern part of the heavens, called *Aurora Borealis*, or Northern Lights. They are irregular in their appearance, assuming different forms and of different degrees of brilliancy. Sometimes they continue for several successive days and nights; and again they are of but a few moments' duration. Sometimes there is a pale illumination spread over a large extent of sky; again large flames waving to and fro, and sweeping from one point of the heavens to the other. Sometimes they assume the form of pillars of fire, and at other times appear like slender fibrous rays of light, majestically moving along the horizon. These movements are occasionally accompanied with a hissing noise, or a low

rumbling, resembling distant thunder. In the Polar regions where the shivering inhabitants have one long night of six months, these lights assume an intense brilliancy, and aided by the other luminaries of the evening sky give almost the light of day, during the dreary interval of the absence of the sun. Scarcely anything can surpass the splendor which these phenomena assume, as they glitter in the clear atmosphere of the frigid zone, and are reflected from its mantle of eternal snow. In the northeastern districts of Siberia, according to the description of Gruelin,* the Aurora is observed to 'begin with single bright pillars rising in the north, and almost at the same time in the northeast; which gradually increasing, comprehend a large space of the heavens, rush about from place to place with incredible velocity, and finally cover almost the whole sky up to the zenith, and produce an appearance, as if a vast tent were expanded in the heavens glittering with gold, rubies and sapphire. A more beautiful spectacle cannot be painted. But whoever should see such a northern light for the first time, could not behold it without terror. For however fine the illumination may be, it is attended, as I have learned from many persons, with such a hissing, crackling and rushing noise through the air, as if the largest fire works were playing off. To describe what they then hear, they make use of the expression *spolochi chodjat*, that is, the raging host is passing. The hunters who pursue the white and blue foxes in the confines of the icy sea, are often overtaken in their course by these northern lights. Their dogs are then so much frightened that they will not move, but lie obstinately upon the ground till the noise is passed.'

The inhabitants of the southern hemisphere witness similar lights in the south, which they therefore denominate Aurora Australis or southern lights. Says Captain Cook, 'on Feb. 17, 1773, in south latitude 58°, a beau-

* Gruelin was a German, born about the year 1700. A man of distinguished abilities, and of a scientific mind. He was a member of the Academy at Petersburg, and obtained much celebrity by publishing a journal of his travels in Siberia.

tiful phenomenon was observed during the preceding night, which appeared again this and several following nights. It consisted of long columns of clear white light shooting up from the horizon to the eastward, almost to the zenith, and gradually spreading on the whole southern part of the sky. These columns were sometimes bent sideways, at their upper extremities, and though in most respects similar to the northern lights in our hemisphere, yet differed from them in being always of a whitish color, whereas ours assume various tints, especially those of a fiery and purple hue.'

Many conjectural opinions have been formed concerning the cause of this phenomenon. Some have supposed it to be caused by rays of light reflected from the immense masses of ice floating in the northern ocean. Others have supposed it inflammable air. It is now pretty generally admitted that electricity is the agent in producing these appearances. Every theory upon the subject is however conjectural and no one perfectly satisfactory. There can be but little doubt that electricity (which is the same with lightning) is the agent. But how to account for its accumulation at the poles, and for the peculiar phenomena which it there exhibits, is difficult. The following theory is perhaps more plausible than any other which has been presented.

'The great quantity of vapor rising between the tropics forms clouds, which contain much electricity; some of them fall in rain, before they come to the polar regions. Every drop brings down some electricity with it; the same is done by snow or hail; the electricity so descending, in temperate climates, is received and imbibed by the earth. If the clouds be not sufficiently discharged by this gradual operation, they sometimes discharge themselves suddenly, by striking into the earth, when the earth is fit to receive their electricity. The earth in temperate and warm climates, is generally fit to receive it, being a good conductor.

'The humidity contained in all the equatorial clouds that reach the polar regions, must there be condensed, and fall in snow. The great cake of ice that eternally covers those regions may be frozen too hard to permit

the electricity's descending with that snow, to enter the earth. It may therefore be accumulated on the ice. The atmosphere being heavier in the polar regions than in the equatorial, will there be lower, as well from that cause as from the smaller effect of the centrifugal force; consequently the distance of the vacuum above the lower part of the atmosphere will be less at the poles than elsewhere, and much less than the distance (upon the surface of the globe,) extending from the poles to those latitudes in which the earth is so thawed as to receive and imbibe electricity. May not then the great quantity of electricity brought into the polar regions by the clouds which are condensed there, and fall in snow, which electricity would enter the earth, but cannot penetrate the ice; may it not, as a bottle overcharged, break through that low atmosphere, and run along in the vacuum over the air towards the equator; diverging as the degrees of longitude enlarge, strongly visible when densest, and becoming less visible as it more diverges; till it finds a passage to the earth in more temperate climates or is mingled with the upper air? If such an operation of nature were really performed, would it not give all the appearances of an *Aurora Borealis*? And would not the Auroras become more frequent after the approach of winter; not only because more visible in longer nights, but also because in summer the long presence of the sun may soften the surface of the great ice cake, and render it a conductor by which the accumulation of electricity in the polar regions will be prevented?

This theory is confirmed by the fact that if you exhaust a glass vessel of the air, and then charge it with electricity, the electric fluid in the vacuum exhibits all the appearances of the *Aurora Borealis*. When the vessel is most perfectly exhausted, the electric fluid appears quite white; when a little air is introduced, it assumes more of a purple hue.

At different periods of the world, and in various countries, there have been brilliant illuminations of the heavens, resembling fiery arches, and clouds, and flaming

swords, and contending armies. These are generally a great source of terror to the ignorant and superstitious. Though so different in the form they assume from the usual appearance of the northern lights, they are generally to be ascribed to the same cause.

It is hoped, however, that as science advances, the causes of this phenomenon will be more clearly revealed.

II. *Shooting Stars or Fire Balls.*—There are other celestial or atmospherical phenomena, differing so entirely from the Aurora Borealis in appearance as to be undoubtedly different in origin. Fiery Balls shoot with rapidity through the heavens, emitting for a moment a brilliant light, and then becoming suddenly and silently extinguished. Sometimes they burst with a loud explosion and disappear, or falling, are extinguished in the ocean or sink deep beneath the surface of the ground. Many of these meteors appear to be of a gaseous nature, which in some unaccountable way are collected and inflamed, and which blaze for a moment and are gone. Whence they came, or whither they go, or by what power impelled, we cannot say. The only knowledge we can have of their existence is from the momentary glitter with which they dazzle the eye. These meteors are seldom of more than a few moments' duration, and sometimes have rivalled the sun in splendor and turned the night into day. They have occasionally been traced from one second to two or three seconds, but are not often of so long existence. They are of various shades and dimensions and of divers colors. But they agree with great uniformity, in their transient appearance, in their velocity and elevation. Their height has been very generally calculated at from fifty to sixty miles above the surface of the earth, and their velocity at from twenty to thirty miles a second. Numerous hypotheses have been advanced to account for these extraordinary phenomena. Some have supposed them luminous vapors; some electrical appearances; some volcanic substances propelled into the atmosphere by explosions of great violence: others suppose that some of them are of a gaseous nature, fortuitously collected in the atmosphere, and the more compact of them are thrown from volcanos in the moon. None of these theories are

perfectly satisfactory. A famous meteor was observed passing over Italy in March, 1676. About an hour and three quarters after sunset, thousands of eyes were attracted by a ball of fire, flying with immense velocity through the air. Scientific men computed its height to be at least thirtyeight miles. The ball itself was above half a mile in diameter and moved with the immense rapidity of one hundred and sixty miles in a minute of time. It was heard to make a hissing noise as it passed along, like that of artificial fireworks. As it left the main land at Leghorn and passed off to sea towards Corsica, it was heard to give a report like a heavy cannon; immediately after which another sound was heard like the rattling of a great cart running over stones. It is difficult to imagine by what natural powers this huge body could have been collected, or how an impulse could have been communicated to send it with such amazing velocity.

A wonderful meteor somewhat resembling that just described, was seen all over England in March, 1819. The following description is given by an eye witness.

‘Sir Hans Sloane mentions that once walking in the streets of London at about a quarter past eight o’clock in the evening, he was surprised to see a sudden great light far exceeding that of the moon, which shone very bright. He turned to the westward where the light was, which he apprehended at first to be artificial fire-works, or rockets. Its color was whitish with an eye of blue, of a most vivid dazzling lustre, which seemed in brightness very much to resemble if not to surpass, that of the body of the sun in a clear day. This brightness obliged him to turn his eyes from it several times, as well when it was a stream, as when it was pear fashioned and a globe. There was left behind it, when it had passed, a track of a cloudy or faint reddish yellow color, such as red-hot iron or glowing coals have, which continued more than a minute, seemed to sparkle, and kept its place without falling. This track was interrupted, or had a chasm towards its upper end, at about two thirds of its length. He did not hear any noise it made; but the place where the globe of light had been, continued for some time after it was extinct, of the same reddish color with the stream,

and at first some sparks seemed to issue from it, such as come from red-hot iron beaten out on an anvil. The splendor was little inferior to that of the sun; within doors the candles gave no manner of light; and in the streets not only all the stars disappeared, but the moon, then nine days old, and high near the meridian, the sky being very clear, was so far effaced as to be scarcely seen; at least not to cast a shade, even where the beams of the meteor were intercepted by the houses; so that for some few seconds of time it in all respects resembled perfect day. A loud noise followed the explosion of this meteor, accompanied by an uncommon tremor of the air, which sensibly shook the glass windows and the doors of houses, and in some places the houses themselves. It is generally admitted that this meteor must have been composed of inflammable vapor or gas; but how generated, how inflamed, and whence it received its impulse, it is difficult to imagine. Any solution hitherto suggested, hardly falls within the limits of possibility. It will at once be perceived that the transient appearance of these meteors preclude the possibility of a careful examination. Nothing relative to them causes greater astonishment than the excessive light they emit. The illumination often obliterates the stars, makes the moon look dull, and dazzles the night with the brilliancy of day. There are many instances in which such meteors have made a splendid appearance in full sunshine. They are undoubtedly of as frequent occurrence in the day as in the night, but being eclipsed by the superior splendor of the sun, do not attract the eye.'

A celebrated meteor was observed in England, August 18, 1783, the following account of which was given by the late Mr Cavallo.* 'On the evening of the 18th of August, 1783, we were standing upon the northeast corner of Windsor† terrace. The weather was calm and

* Mr Cavallo, was the son of a physician at Naples, and was born in 1749. He removed to England and devoted himself exclusively to scientific pursuits. Many valuable treatises in the transactions of the Royal Society are from his pen. He died in London in 1809.

† Windsor on the Thames, 22 miles west of London, the favorite country residence of the British Kings.

agreeably warm. The sky was serene, excepting very near the horizon, where a haziness just prevented the appearance of the stars. A narrow, rugged and oblong cloud stood on the northwest side of the heavens, reaching from the extremity of the haziness, which rose as high as 18 or 20 degrees, and stretching itself for several degrees towards the east in a direction nearly parallel to the horizon. It was a little below this cloud, and consequently in the hazy part of the atmosphere, about the north by west half west point of the compass that this luminous meteor was first perceived. Some flashes of lambent light, much like the Aurora Borealis, were first observed on the Northern part of the heavens, which were soon perceived to proceed from a roundish luminous body, nearly as big in diameter as the semi-diameter of the moon, and almost stationary in the above-mentioned point of the heavens. It was then about twentyfive minutes after nine o'clock in the evening. The ball at first appeared of a faint bluish light, perhaps from being just kindled, or from its appearing through the haziness; but it gradually increased in light, and soon began to move, at first ascending above the horizon in an oblique direction towards the east. Its course in this direction was very short, perhaps of five or six degrees; after which it directed its course towards the east, and moving in a direction nearly parallel to the horizon, reached as far as the southeast by east point, where it finally disappeared. The whole duration of the meteor, was half a minute or rather less, and the altitude of its track, seemed to be about 25 degrees above the horizon. A short time after the beginning of its motion, the luminous body passed behind the above-mentioned cloud, without actually seeing the body from which it proceeded for about the sixth or at most the fifth part of its track; but as soon as the meteor emerged from behind the cloud its light was prodigious. Every object appeared very distinct; the whole face of the country, in that beautiful prospect before the terrace, being instantly illuminated. At this moment the body of the meteor appeared of an oblong form; but it presently acquired a tail, and soon after it parted with several small bodies, each having a tail or elongation; and all moving

in the same direction, at a small distance from each other, and very little behind the principal body, the size of which was gradually reduced after this division. In this form the meteor moved as far as the southeast by east point, where the light decreasing rather abruptly, the whole disappeared.

‘During the phenomenon no noise was heard by any of our company excepting one person, who imagined to have heard a crackling noise, something like that which is produced by small wood when burning. But about ten minutes after the disappearance of the meteor, and when we were just going to retire from the terrace, we heard a rumbling noise as if it were of thunder at a great distance, which in all probability was the report of the meteor’s explosion; and it may be naturally imagined that this explosion happened when the meteor parted into small bodies, viz. at about the middle of its track.’ From the interval between the apparent explosion, and the time the report was heard, the distance of the meteor from the spectators may be easily computed. Sound is ascertained to travel at the rate of 1150 feet per second.* About ten minutes elapsed after the disappearance of the meteor before the report was heard. From these particulars the following calculations have been made with mathematical accuracy respecting the distance, altitude, course, and diameter of this meteor. It is, however, obvious, that if the noise heard was not that of the meteor’s explosion, or, if the meteor did not explode when it appeared to, the following results must be considered as altogether useless.

Distance of the Meteor from Windsor castle, . . .	130 miles.
Length of path described in the heavens, . . .	550 miles.
Diameter of the luminous body when it came out of the clouds,	1070 yards.
Its height above the surface of the earth, . . .	36½ miles.

* The rapidity with which sound travels is easily ascertained by experiment. When a cannon is fired, a spectator at a distance, sees the flash some time before he hears the report. Then by measuring the distance between the cannon and himself, and observing the time which elapsed between the flash and the report, he learns how long it took the sound to travel that distance. In the same manner you may learn the distance of thunder, by observing the interval between the flash and the report.

It has been remarked that all large meteors have made their first appearance in the northwest and passed on to the southeast, or precisely the reverse, moving very nearly in the line of the present magnetical meridian.

METEORIC STONES.

Many accounts are upon record in which the explosion of fire balls has been followed by a shower of stones; some so large as to sink many feet into the earth, and others so small as to lie loosely upon its surface. These stones, in consequence of their falling from luminous bodies or meteors, are called Meteoric Stones or Meteorites. These meteors burst with an explosion, and then the shower of stones falls to the earth. Sometimes the stones continue luminous till they reach the earth, but usually their luminousness disappears at the time of the explosion. Their size differs from a few ounces to several tons. They all resemble each other though falling in the most distant parts of the globe. They are all composed of nearly the same ingredients and completely differ from every other known stone. It seems therefore that these stones must have some common origin—for it seems otherwise inconceivable that in India, England, France, Germany, Italy, and America, stones should have fallen which differ from every other mineral in the countries in which they are found, and which almost exactly resemble one another. In France, in 1492, a huge stone was seen to fall immediately after a loud thunder clap. On going to the place a hole was discovered, and digging out the stone, it was found to have entered three feet deep, and weighed 260 pounds. ' In 1790, in France, about ten at night, a luminous ball was seen traversing the atmosphere with great rapidity, and leaving behind it a train of light which lasted about fifty seconds. Soon a loud explosion was heard and sparks were seen flying off in all directions. This was soon after followed by a fall of stones over a considerable extent of ground and at various distances from each other. These were all alike in appearance, but of many different sizes, the greater number weighing about two ounces, but many a vast deal more; some fell with a hissing noise and entered the

ground, but the smaller ones remained on the surface. The shower did no considerable damage, only breaking the tiles of some of the houses.' These showers are not always, however, harmless. In Bordeaux, in 1789, a stone fell through the roof of a cottage and killed a herdsman and some cattle. Parts of this stone are now preserved in the Museum at Bordeaux.

The following is an account of some meteorites which fell in Tennessee, May 9, 1827. It is given on the authority of the Rev. Hugh Kirkpatrick.

'On Wednesday the 9th inst. about 4 o'clock P. M., the day being as clear as usual, my son and servants were planting corn in the field; they heard a report similar to that of cannon, which was continued in the air, resembling the firing of cannon or muskets by platoons, and the beating of drums as in a battle. Some small clouds with a trail of black smoke, made a terrific appearance, and from them without doubt, came a number of stones with a loud whizzing noise, which struck the earth with a sound like that of a ponderous body. One of those stones my son heard fall about fifty yards from where he was. In its descent it struck a tree, of the size of a small handspike, and tore it to pieces as lightning would have done. Guided by the tree he immediately found the spot, and there he found the stone about eight or ten inches under the ground. This stone weighed five pounds and a quarter; Mr James Dugge was also present. They stated that the stone was cold, but had the scent of sulphur.'

'On the same day and about the same time, Mr Peter Kitsing was in the field with his laborers, about one mile distant, when a stone fell which weighed eleven pounds and a half. A number of respectable men were present when it was found and taken up. It was twelve inches under the ground. I have seen one that fell at Mr David Garrett's, and part of one that fell at Mr John Bones', and have also heard of one more that has been found. These stones are perfectly similar, glazed with a thin black crust, and bear the marks of having been through a body of fire and black smoke. Many gentlemen who have been incited within a few days to come

to my house to see them, say they never saw such before.'

This stone was analyzed by Mr Leybert, a gentleman of distinguished skill in this peculiarly difficult kind of investigation. According to his analysis, the stone was found to be composed of the following ingredients :

	Per 100 parts.	
Silica, - - -	40	
Protoxide of Nickel, -	2 166	
Magnesia, - - -	23 833	
Alumina, - - -	2 466	
Protoxide of Chrome, -	0 833	
Metallic Iron, - - -	12 000	
Per Oxide of Iron, - -	12 200	
Sulphur, - - -	2 433	
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	95 931	
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	4 069	[metrical Moisture.
		Loss and Hygro-

All the Meteorites, in whatever part of the world they have fallen, are composed of nearly the same ingredients. Where do these stones come from ? This is a question which as yet remains unanswered. We may safely infer that these bodies have not been thrown from any terrestrial volcano; for no native minerals of a similar nature have been found in any part of the globe; neither can the phenomena attending them be accounted for upon this hypothesis; neither are there any known volcanos in many parts of the world in which they have fallen, from which they could have been thrown; some have supposed that they were formed in the upper parts of the atmosphere. But there are no known laws of nature which allow us to assign them this origin. A splendid theory has been erected, which supposes them to have been thrown from some volcano of the moon. This is the most probable supposition, still it is not free from many difficulties. The Journal of Philosophical Transactions remarks, that it appears impossible to ascribe these phenomena to a formation in the superior parts of the atmosphere, or to the irruptions of terrestrial volcanos; but it is possible for such masses to be projected

from the moon so as to reach the earth ; and that all the phenomena of these meteors or falling stones, have a surprising conformity with the circumstances which would be expected to attend masses, expelled from the moon by natural causes. These things unite in forming a body of strong evidence, that this is, in all probability actually the case. All those luminous balls however, which occasionally make their appearance in the heavens, are involved in much obscurity. They may be all of the same origin ; they may be of different natures. Their transient appearance awakens a curiosity which science as yet is unable to allay.

Falling Stones. — Many persons have expressed much incredulity respecting the reality of stones falling from the atmosphere. I have just been examining a stone which fell in Virginia ; it very much resembles that which fell in Tennessee as described in this tract. No one who has attended to this subject can have the least doubt respecting the reality and the frequency of this phenomenon. A stone fell in Forsyth, in Georgia, in May, 1829. It is thus described by an eye-witness : ‘ Between three and four o’clock, on the 8th instant, a small black cloud appeared south from Forsyth, from which two distinct explosions were heard, following in immediate succession, succeeded by a tremendous rumbling or whizzing noise, passing through the air ; which lasted from the best accounts from two to four minutes. This extraordinary noise was, on the same evening accounted for by Mr Sparks and Captain Portian, who happened to be near some negroes working in a field, one mile south of this place, who discovered a large stone descending through the air, weighing, as was afterwards ascertained, thirtysix pounds. The stone was in the course of the evening, or very early the next morning recovered from the spot where it fell. It had penetrated the earth two feet and a half. The outside, wore the appearance as if it had been in a furnace : it was covered about the thickness of a common knife blade, with a black substance somewhat like lava that had been melted. On breaking the stone, it had a strong sulphurous smell, and exhibited a metallic substance resembling silver. The stone however when broken, had a white

appearance on the inside, with veins. By the application of steel it would produce fire.

'The facts, as related, can be supported by many individuals who heard the explosion and rumbling noise, and saw the stone.'

Dr Boykin of Georgia remarks, 'no one can tell from what direction the meteor came. The first thing noticed was the report, like that of a large piece of ordnance; some say the principal explosion was succeeded by a number of lesser ones in quick succession, similar to the explosions of a cracker; one has told me the secondary noise was only a reverberation. Very soon after the explosion some black people heard a whizzing noise, and on looking saw a faint smoke descend to the ground; at which time they heard the noise produced by the fall of the stone; they ran to the spot, for they saw where it fell, and discovered the hole it had made in the ground, being more than two feet in a hard clay soil. The negroes and others who went early to the spot, say they perceived a sulphurous smell. The stone weighed thirtysix pounds; it fell at a small angle with the horizon.'

Had this matter appeared in the night, it would undoubtedly have appeared luminous, but the superior splendor of the sun so far eclipsed it that its brilliancy was unobserved. All these meteorites contain iron. There is however a class of meteorites a little different from those just described, consisting almost entirely of iron. Large quantities of iron are found on the surface of the earth, lying in loose insulated masses, and at great distances from any mines of iron. These in their appearance and situation give indubitable evidence of having been ejected from some volcano, or having descended from the air. Meteoric iron is generally whiter and more malleable than common iron. Some of these masses have been seen to descend; they have undoubtedly a very intimate connexion with the meteoric stones, and probably are of the same origin. A large mass of this iron, weighing 30,000 pounds, has been found in the province of Tucuman, in South America. In many other parts of the world similar masses have been found. One is now in the cabinet of Yale College,

which was found in Louisiana; its weight exceeds 3000 pounds. It contains nickel, and probably a little carbon, and is less easily oxidated than purified iron. Several large masses have recently been found in the valley of the Mississippi. Mr Sowerby, an English mineralogist, presented the Emperor Alexander a sword 2 feet long and $1\frac{3}{8}$ inches wide, hammered at a red heat from a mass of meteoric iron found in Africa. He received in return a ring set with diamonds, and inclosing an emerald in the centre. The descent of these bodies is indeed a wonderful phenomenon; and there is no theory presented the public as yet, which satisfactorily accounts for all the like appearances attending them. Says Prof. Cleaveland, 'The similarity of aspect and composition in almost all meteoric stones, hitherto examined, indicates a common origin. But this origin is yet unknown. It is impossible to say when, or in what manner, meteoric stones have been formed. We can do no more than to state the four principal conjectures upon this subject, namely — 1. Meteoric stones are formed in the atmosphere. 2. They are projected from terrestrial volcanos. 3. They proceed from lunar volcanos. 4. They are fragments detached from terrestrial comets.'

The following well authenticated instances of stones falling from the air will interest the reader.

November 27, 1627, the sky being quite clear, Gassendi, a celebrated astronomer, saw a burning stone fall on mount Vaisir, in the southeast extremity of France, near the city of Nice, on the coast of the Mediterranean sea. While in the air it seemed to be about 4 feet in diameter; it was inclosed in a luminous circle of colors like a rainbow; and in its fall it produced a sound like the discharge of cannon. It weighed 59 lbs. was very hard, of a dull metallic color, and in specific gravity considerably more than that of marble.

Prior to this is another remarkable instance in the stone that fell near Ensisheim, a considerable town in Alsace, the northeast point of France, near the upper Rhine, a little north of Brazil. This was in 1492. November 7, between eleven and twelve, before noon, when a dreadful thunder clap was heard at Ensisheim, a child saw a large stone fall on a field lately sowed with wheat. On the

people going to the place the hole was found, and digging out the stone it was found to have entered three feet deep and weighed 360 lbs, which makes its size equal to a cube of about thirteen inches the side. No doubt has ever been entertained of this fact; and cotemporary writers all agree in its general belief by the neighborhood, and the natives of the place must have known that in their wheat field no such stone or hole had formerly existed.

In September, 1753, several stones fell, accompanied with loud noises in the province of Bresse, a little west of Geneva; particularly one fell at Pont-de-Vesle, and one at Liponas, at nine miles' distance from each other. The sky was clear, and the weather warm. A loud noise and hissing sound were heard at those two places, and for many miles round, at the time the stones fell. The stones appeared exactly similar to each other, of a darkish, dull color, very heavy, and their surface showing as if they had suffered a violent degree of heat. The largest weighed about 20 lbs., and penetrated about six inches into the ploughed ground; a circumstance which renders it highly improbable that they could have existed there before the explosion. This phenomenon has been described by the astronomer Delalande, who seems to have carefully examined on the spot the truth of the circumstances he describes.

It is related by Paul Lucas, the traveller, that when he was at Larissol, a town in Greece, near the gul of Salonica, a stone of 72 lbs. weight fell in the neighborhood. It was observed to come from the northward, with a loud hissing noise and seemed to be enveloped in a small cloud, which exploded when the stone fell. It looked like iron dross and smelled of sulphur.

In the year 1768, three stones were presented to the Academy of Sciences at Paris, which had fallen in different parts of France; one at Luce, in the Maine; another at Aire in the Artois, and the third at Cotentin. These were all externally of the very same appearance; and Messrs Fougereaux, Cadet, and Lavoisier, drew up a particular report on the first of them. They state, that on the 18th of September, 1768, between four and five, afternoon, there was seen near the village of Luce, in Le

Maine, a cloud, in which a sharp explosion took place, followed by a hissing noise, but without any flame; that some persons, about 10 miles from Luce, heard the same sound: looking upwards, they perceived an opaque body, describing a curve line in the air, and fall on a piece of green turf near the high road; that they immediately ran to this place, where they found a kind of stone, half buried in the earth, extremely hot, and weighing about $7\frac{1}{2}$ lbs.

December 18, 1795, several persons near Captain Topham's house in Yorkshire, heard a loud noise in the air, followed by a hissing sound, and soon after felt a shock as if a heavy body had fallen to the ground at a little distance from them; in fact one of them saw a huge stone fall to the earth at eight or nine yards from the place where he stood; it was seven or eight yards above the ground when he first observed it; in its fall it threw up the mould on every side and buried itself twentyone inches deep; the stone being raised was found to weigh 56 lbs.

March 17, 1798, a body burning very brightly, passed over the vicinity of Villa Franche on the Saone, a little to the east of Lyons, in France, accompanied with a hissing noise and leaving a luminous track behind it. This phenomenon exploded with a great noise about 1200 feet from the ground; and one of the splinters, still luminous, being observed to fall in a neighboring vineyard was traced: at the spot a stone was found about a foot in diameter, which had penetrated twenty inches into the ground.

An account of a phenomenon of precisely the same description, was received from the East Indies, vouched by authority particularly well adapted to procure general respect. Mr Williams, F. R. S. residing in Bengal, hearing of an explosion with a descent of stones, in the province of Bahar, diligently inquired into the circumstances among the Europeans upon the spot. He learned that on December 19, 1798, at eight o'clock in the evening, a large fire ball or luminous meteor was seen at Benares, and other parts of the country; that it was attended with a loud rumbling noise; and that about the same time the inhabitants of Krakhut, fourteen miles from

Benares, saw the light, heard a report like a loud thunder clap, and immediately after heard the noise of heavy bodies falling in the neighborhood. Next morning the mould in the fields was found to have been turned up in many spots, and unusual stones of various sizes, but of the same substances, were picked out of the moist soil, generally from a depth of six inches. As the occurrence took place in the night, after the people had retired to rest, the explosion and fall of the stones were not seen : but the watchman of an English gentleman near Krakhut, brought him a stone the next morning which he said had fallen through the top of his hut, and buried itself in the earthen floor.

It seems quite impossible to deny very great weight to all these testimonies, and many others that might be given, several of them by intelligent eye witnesses, and others by more ordinary persons indeed, but prepossessed by no theory ; all concurring in these descriptions ; and examined by acute and respectable persons, immediately after the phenomena had occurred. Without offering any further remarks then, on this mass of external evidence, we shall only just notice the main points, which it seems to substantiate in a very satisfactory manner. It proves, then, that, in various parts of the world, luminous meteors have been seen moving through the air with surprising rapidity, in a direction more or less oblique, accompanied with a noise, commonly like the whizzing of a large shot, followed by an explosion, and the fall of hard, stony, or semi-metallic masses, in a heated state. The constant whizzing sound ; the fact of stones being found, similar to each other, but unlike all others in the neighborhood, at the spots towards which the luminous body, or its fragments were seen to move ; the scattering or ploughing up of the soil in these spots, always in proportion to the size of the stones ; the concussion of the neighboring ground at the time ; and especially the impinging of the stones on bodies somewhat above the earth, or lying loose on its surface — are circumstances perfectly well authenticated in these reports ; proving that such meteors are usually inflamed hard masses, descending rapidly through the air to the earth.

The following table contains some of the other most remarkable cases of falling stones, which have occurred, with the authorities for each.

Substances.	Where they fell.	Time.
Showers of stones. - - -	Rome. -	Before Christ.
Showers of stones. - - -	Rome. - -	"
Showers of Iron. - - -	Lucania. -	"
A very large stone. - - -	Thrace. -	"
Three large stones. - - -	Thrace. -	"
Showers of fire. - - -	Quesnoy. -	January.
Stone of 72 lbs. - - -	Macedonia. -	January.
About 1200 stones — one of 120 lbs. another of 60 lbs. }	Italy. " -	1510.
Another of 53 lbs. - - -	Provence. -	November.
Showers of sand for fifteen hours. -	In the Atlantic. -	April.
Showers of rain - - -	Mansfield. -	1658.
The same. - - -	Copenhagen. -	1646.
Showers of sulphur. - - -	Brunswick. -	October.
Ditto, of a viscid, unknown matter. -	Ireland. - -	1659.
Two large stones weighing 20 lbs. -	Bresse. -	September.
A stony mass. - - -	Normandy. -	1750.
A stone of 7½ lbs. - - -	Le Maine. -	1768.
A stone. - - -	Artois. - -	1768.
A stone. - - -	Le Cotentin. -	1768.
Extensive showers of stones. - - -	Agen. - -	1790.
About twelve stones. - - -	Tuscany. - -	1794.
A large stone of 56 lbs. - - -	Yorkshire. -	1795.
A stone of about 20 lbs. - - -	Sate. - -	1798.
A stone of 10 lbs. - - -	Portugal. - -	1796.
Showers of stones. - - -	- - -	1798.
Showers of stones. - - -	Bohemia. -	1753.
Mass of iron 70 cubic feet. - - -	America. - -	1800.
Mass of iron 14 quintals. - - -	Siberia. - -	Very old.
Showers of stones. - - -	Barbonton. -	1789.
Large stone of 220 lbs. - - -	- - -	1792.
Two stones 200 and 300 lbs. - - -	Verona. -	1762.
A stone of 20 lbs. - - -	- - -	1798.
Several stones from 10 to 17 lbs. -	Normandy. -	1803.

One curious hypothesis has been advanced in relation to meteoric stones, which we cannot refrain from noticing before closing our remarks on this part of our subject. We offer it, not as a satisfactory explanation of the phenomena, but as a specimen of the ingenuity with which philosophers have sought to explain the wonderful appearances of nature.

It had long been known that between Mars and Jupiter, in the solar system, there was a large space entirely unoccupied by any discovered planet. The attention of

philosophers was accordingly directed to this part of the heavens, until, in the nineteenth century, four very small planets were discovered, which have been called, from their diminutive size, asteroids. Their names are Vesta, Juno, Pallas, Ceres. One of them is estimated to be only eighty miles in diameter. The estimates, however, vary very much.

The most remarkable circumstance, however, which is connected with these asteroids, is this. They all have *very nearly the same average distance from the sun*, the *same period of revolution* in their orbits—they are of the *same density*; that is, the matter which composes them is of the same weight—and in the points at which each of them approach the sun, called their perihelions, and in those where their orbits cross the elliptic, all the asteroids agree.

These are certainly extraordinary coincidences. They have given rise to the hypothesis that these four bodies were originally one large planet, which by some vast convulsion, of which we can know nothing in detail, was rent asunder, separating itself into four large, and a multitude of small fragments. These four large fragments, it is supposed, continue to revolve around the sun, very nearly in the place of the original revolution of the whole; each one deviating from the former track, according to the impulse given it by the shock.

But what connexion has all this, the reader will ask, with meteoric stones? The theory which we are endeavoring to explain, imagines that some smaller fragments from this fancied explosion, were thrown to a great distance from the original place of the planet, and that many of them came into the vicinity of our earth, and that they are now revolving about it, like satellites. While they are moving in the empty space beyond the earth's atmosphere, they are invisible. They sometimes, however, are supposed to dip into the atmosphere, for their orbits being probably very elliptical, they may at times approach very near the body of the earth. When they thus enter the earth's atmosphere, the friction of the air disengages *light* and *heat*. The former makes these bodies visible to us, and the latter, the heat, cracks off portions of the revolving body, which fall to the earth. The main

fragment is then supposed to pass out of the atmosphere, and to continue its revolution until again it approaches the earth, and by dipping into its atmosphere, produces again the same effects.

In corroboration of this hypothesis it may be said,

1. The stones which fall at any time, are always very small, in comparison with the observed magnitude of the meteor moving through the air.

2. The stones, as it is said, are always hot, if examined immediately after they fall.

3. The stones are all similar in character. It ought however to be added that their density is much greater than the mean density of the asteroids.

4. The noise which precedes the falling of the stones is a rapid succession of reports, like the irregular discharge of musketry.

5. The meteor which is usually seen before the fall of the stones, has always a rapid motion, and that not in a direction towards the earth, but parallel, or slightly inclined to the horizon.

We do not offer this opinion as a satisfactory explanation of the phenomena, nor do we condemn it as fanciful. It is presented for the reader's consideration.

III. *Ignes Fatui*. With the *Ignes Fatui*, familiarly known by the name of the Will o' the Wisp, we are better acquainted than with those more sublime meteors which ride higher in the heavens, and by the rapidity of their flight, and their momentary existence, elude investigation. To the ignorant and superstitious the *ignes fatui* are a source of terror. The appearance of these harmless lights in a marsh has made many a poor simpleton tremble with fright. But it would be just as wise to be frightened by the dense fog which rises from the bosom of the lake, or to be appalled by the cheerful blaze of the wintry fire. These luminous bodies are always seen in marshy lands. Sometimes they are caused by the decomposition of vegetable substances, forming something of the nature of lightwood, with which every one is acquainted. The light emitted from these decaying bodies, and seen through the damp exhalations of the marsh is magnified, as the sun when setting behind a thin veil of clouds, expands to double its usual apparent

form. Some of these marshy meteors appear to change their situation, and dance about from place to place. They are composed of inflammable air, which is continually evaporating in the low stagnant grounds where these phenomena make their appearance. The earth is continually exhaling hydrogen gas, phosphorus, carbonic acid gas, and occasionally sulphurous vapors. These gases readily inflame from a great variety of natural causes, to which they are perpetually exposed. They may be inflamed by electricity, or by heat generated during the decomposition of animal or vegetable materials. Now this mass of gas being on fire will burn till its inflammable principle is destroyed. In proportion to its greater or less degree of combustible power, it will pour forth a greater or less degree of light. From the levity of the burning vapor, it will wave to and fro, in the currents of the air, like any gas light exposed to the wind; sometimes flaming higher and again sinking down to a feeble flicker; thus constantly moving before the spectator, and assuming different forms and colors, according to the varying density of the fog through which it is seen. A friend of mine, says Rev. John Mitchell, returning from abroad late in the evening, had to cross a strip of marsh. As he approached the causeway he noticed a light towards the opposite end, which he supposed to be a lantern in the hand of some person whom he was about to meet. It proved however to be a solitary flame, a few inches above the marsh, at the distance of a few feet from the edge of the causeway. He stopped some time to look at it, and was strongly tempted notwithstanding the wariness of the place, to get nearer to it, for the purpose of closer examination. It was evidently a vapor issuing from the mud, and becoming ignited, or at least luminous, in contact with the air. It exhibited a flickering appearance, like that of a candle expiring in its socket; alternately burning with a large flame, and then sinking to a small taper; and occasionally for a moment becoming quite extinct. It constantly appeared over the same spot. This same gentleman remarks that the locomotive power with which these meteors seem to be endowed, is probably apparent only, not real. As the light dwindles away, it will seem to move from you, and with a velocity

proportioned to the rapidity of its diminution. Again as it grows larger, it will appear to approach you. If it expires by several flickerings or flashes, it will seem to skip from you, and when it reappears you will easily imagine that it has assumed a new position.

It is sometimes thought that you cannot approach an ignis fatuus; that it will recede as rapidly as you advance. This is probably the effect of imagination. In a misty night, a traveller easily mistakes one of these lights, for the light of a neighboring house, and going in pursuit of it, he finds hedges and bogs and mire, till he is led to the middle of a swamp. It is stated by Mr Mitchell that a man left his neighbor's house late in the evening and at daylight had not reached his own, a quarter of a mile distant: at which his family being concerned, a number of persons went out to search for him. We found him near a swamp with soiled clothes, and a thoughtful countenance, reclining by a fence: The account he gave was, that he had been led into the swamp by a jack o' lantern. His story was no doubt true, and yet had little of the marvellous in it. The night being dark, and the man's senses a little disordered withal, by a glass too much of his neighbor's cherry, on approaching his house he saw a light, and not suspecting that it was not upon his own mantel, made towards it. A bush or bog might have led to the same place, if he had happened to take it for his chimney top. These are some of these marshy lights which cannot as yet be scientifically explained. But repeated observations and successive experiments are removing one difficulty after another, and the time may yet come when the science of meteors shall be as simple and satisfactory as any other which elucidates the mysteries of nature.

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SCIENTIFIC TRACTS.

NUMBER XV.

LIFE OF COLUMBUS.

IT is remarkable that, after all the elaborate investigations of many writers, the early biography of Columbus is still wanting in several interesting particulars. As to his birth, for example, it is only made to appear probable that he was born about the year 1435 or 1436. The place of his nativity, also, has been the subject of as much and as warm contention as the birth-place of Homer. The original and long settled opinion was in favor of Genoa. But strenuous claims have also been asserted by the Italian States of Placentia and Piedmont : the former connecting the navigator with the household of his great grandfather, who owned a small property in a Piedmontese town ; and the latter making him the son of Dominico Colombo, lord of the castle of Cucurro in Montserrat. There has been a controversy among the Genoese themselves, moreover — to whom, on the whole, other claimants have abandoned the field — whether he was born within their city, or in some one of six or eight villages in other parts of their territory. In one of these it seemed that his family possessed a small farm ; in another, a portrait of him is preserved ; in a third, a public square once bore his name. But the testimony of Columbus himself may be considered decisive of this question. In a will executed in 1498, he twice speaks of ‘being born in Genoa.’ In the same instrument he also commands his son to maintain always in the city of Genoa a person of *his* lineage, ‘to hold footing and rank in that city as a native of it, so that he may have aid

and favor in that city in case of need, *for from thence I came, and there I was born.*' Furthermore, a little breviary was found in the Corsini library at Rome, in the year 1785, bequeathed 'to his beloved country, the Republic of Genoa,' by an informal codicil executed at Valladolid, May 4th, 1506, sixteen days before his death. It is well observed by an historian, as accurate as he is elegant, that the 'sentiments which are manifest in these passages would be without all object, if not directed to the native place of Columbus. He was at this time elevated above petty pride on the subject. His renown, he well knew, would have shed lustre on any hamlet; and the strong love of country here exhibited, would never have felt itself satisfied, until it had singled out the spot and nestled down in the very cradle of his infancy.'

There has been another dispute concerning the lineage of the illustrious discoverer, several noble and ancient families of the same name (in Italian, Colombo) having advanced various theories upon the subject. It is sufficient, however, to say of these, that they were all more or less nearly connected with each other, and with a common though distant origin: and that the great subject of the controversy was probably connected with them all.—It is well ascertained that his immediate ancestors were a line of humble, but worthy citizens, living in Genoa, even from the time of Giacomo Colombo, 'the wool carder,' in 1311; and that the navigator's father was a man of this same trade. Beyond this, it certainly is not necessary to pry into the rolls of his genealogy. Whether his remote ancestors were or were not noble, and whether they did or did not keep hawk or hound, it will be glory enough for his descendants, in all countries and in all times, that he transmitted a brilliant and unsullied name which he is known *not* to have inherited.

It need only be farther observed of his family, that he was the eldest of four children; the history of two of whom, the brothers Bartholemew and Diego, is somewhat connected with his own. His opportunities of education were not remarkable. He was taught to read and write while yet a child, and his writing is said to have been so elegant that he might at any time have earned his

bread by it. He made proficiency also in arithmetic, drawing, design, grammar, and the latin language. But in consequence of decided evidences which he soon gave of a strong passion for geography and navigation, his education was chiefly directed to these studies. He was sent to a famous school at Padua, for a short time, and there instructed in geometry and astronomy, in addition to the studies just named. Here, the foundation was laid in his mind for his future greatness; for he devoted himself to his books with all the ardor and energy of his nature, and late in life he often spoke of this youthful application, as a secret impulse of the Deity, guiding and inspiring him in reference to the great end he was chosen to accomplish. But he could have learned nothing more at Padua than the rudiments of what he studied, for he left that university while yet extremely young, and returned to his father's house at Genoa. Whether he there engaged with *him* in wool-combing does not appear. He could not, however, have continued long in that employment, as his nautical life commenced at the age of fourteen years. Upon this his heart had been long set; and the passion was undoubtedly quickened, as well by the generally reviving and curious spirit of the times, as by the peculiarly maritime and adventurous habits of the Genoese citizens, and the situation of the city itself.

His first voyages were made with an old and hardy sea-captain of his own name, who had acquired considerable reputation by his daring cruises; and who, from a distant relationship, probably took some pains to initiate the young mariner into the toils of the ocean, and the perils of the piratical wars then common in the Mediterranean sea. He was engaged also in an expedition fitted out in 1459, by the Duke of Calabria against Naples. Genoa furnished aid in money and ships on this occasion, and the veteran Colombo probably had a share of the command of their forces. This war, which lasted four years, was finally unsuccessful; but that the young discoverer rather gained than lost honor in the course of it would appear from his being at one time appointed to a separate command, and despatched on a hazardous cruise, to cut out a galley from the harbor of Tunis. A characteristic expedient

which he used at this early period for beguiling a discontented crew into a continuation of the enterprise, by deceiving them as to the ship's course, strongly reminds us of the character which he subsequently developed in still bolder relief. 'When I arrived off Sardinia,' he writes long afterwards, 'I was told there were two ships and a carrack with the galley; by which intelligence my crew were so troubled that they determined to proceed no further, but to return to Marseilles for another vessel and more people. As I could not by any means compel them, I assented apparently to their wishes, altered the point of the compass, and spread all sail. *It was then evening, and the next morning we were within the cape of Carthage, when all were firmly of opinion that they were sailing towards Marseilles.*' After this — though the exact date is not known — he was concerned in a naval exploit of Colombo the younger, nephew to the veteran, and himself so celebrated a corsair, that the Moorish mothers are said to have frightened their unruly children with his name. It was an attack upon four richly laden Venetian galleys, intercepted by the corsair on their return voyage from Flanders. A desperate engagement took place; the vessels grappled each other, and the crews fought hand to hand, and from ship to ship; and thus the battle continued from morning to evening with great carnage upon both sides. The vessel commanded by our young navigator was engaged with a huge Venetian galley. By means of hand-grenades and other fiery missiles, the latter was wrapped in flames; and the two being fastened together by chains and grappling irons, both were involved in the same fire, and soon became a mere burning mass. The crews threw themselves into the sea, and Columbus to save himself seized an oar which was floating within reach, and being an expert swimmer, attained the shore, though five or six miles distant. This action was fought on the coast of Portugal: and such was the occasion of his arrival — by some writers it is said, his first arrival — in the city of Lisbon.

This was about the year 1470, when Columbus is described as in the full vigor of manhood, tall, well formed, muscular, of commanding and dignified manners, moder-

ate and simple in apparel and diet, eloquent in discourse, engaging and affable with strangers. He resided in or about Lisbon for fourteen years. This circumstance was partly owing, no doubt, to a matrimonial connection which he formed with an Italian cavalier's daughter whom he met with in attending religious services, as he did with scrupulous regularity, at the chapel of the convent of All-Saints. The father-in-law being dead, the young couple lived with the mother ; and the latter soon perceiving the interest which Columbus took in maritime matters, told him all she knew of the voyages of her late husband, who had been a distinguished navigator under Prince Henry of Portugal, and brought him all his charts, journals, and memorandums. Columbus devoted himself with unwearied diligence to the examination of these papers, and of whatever others of a similar nature he could obtain. Thus he acquainted himself with all the routes and plans of the enterprising Portuguese. He also occasionally joined in expeditions to the African coast, then a country of great and novel interest. Some other leisure, meanwhile, was devoted to making maps and charts, in which he finally acquired a proficiency then quite rare, and which assisted him, too, in the maintenance of his family. His wife inheriting some property in the recently discovered island of Porto Santo, he went to reside there with her for some time. There, on the very frontiers of discovery, they were frequently visited, no doubt, by the African voyagers going to and fro, while he held daily familiar conversations upon all the popular topics of the day, with Correo, the husband of his wife's sister, a man of influence upon the island and a navigator of great note. This was a period of general excitement, and it is not wonderful that Columbus, situated as he was and had been, and with his ardent temperament, should enter into it with his whole soul.

At this time he seems to have gradually matured his theory concerning undiscovered lands in the west. This was founded, 1. Upon the nature of things. 2. The authority of learned writers. 3. The reports of navigators. Under the first head, he considered the earth to be a sphere, of which about one third still remained unex-

explored. This he believed was occupied by a continuation of the continent of Asia, which might extend so far as to approach the western shores of Africa and Europe, within no very great distance. Of course a navigator would reach Asia, by sailing from east to west, and would discover any intervening land. This reasoning was confirmed in the mind of Columbus, not only by passages of ancient writers, and the more recent travels of Mandeville and Marco Polo in the east, but by various conversations with African voyagers, Portuguese pilots, and the inhabitants of the lately discovered islands. From some of these he learned that a piece of carved wood had been picked up, which must have drifted from the west; and that reeds of an immense size, trunks of huge pine trees of unknown kind, and lastly, the bodies of two dead men of strange features and color, had been cast either upon the main coast or upon some of the neighboring islands. He derived great additional aid from the correspondence of Toscanelli, a learned Florentine; and especially from a map furnished by him, in which the eastern coast of Asia was drawn in front of the western coast of Europe, at a moderate distance. He also procured and perused carefully, the enthusiastic and vague history of Polo. His increasing enterprise is proved by a voyage which he made in 1477, several hundred miles beyond Iceland, (which was then called Thule.)

From the time when the theory of Columbus was matured, it remained unalterably fixed in his mind and heart, and he never afterwards spoke of it with doubt, hesitation or indifference. He is said even to have regarded it with superstitious awe, and to have looked upon himself as a chosen instrument for great future purposes in the hand of Heaven. Several years, however, elapsed, without any steps being taken towards his ultimate design, owing partly to his poverty, and partly to the circumstance that the age was not yet prepared for his theory, or at least for attempting to ascertain its correctness. But the time was fast approaching, and two fortunate events seemed particularly to favor his scheme. One was the application of the astrolabe to navigation; and the other, the commencement of the reign of the enterprising king John II.

of Portugal. It was immediately after the first of these events, that Columbus proposed his voyage of discovery to the king. The latter referred the proposal to a junto of learned men, who treated it as extravagant and visionary; and afterwards to a larger council of prelates and men of science. But the decision was still the same, though the objections were less to the theory itself, than upon the ground of the war with the Moors of Barbary, and other enterprises in which Portugal was already engaged.

Towards the end of 1484, Columbus left Lisbon, with his son Diego, as is generally supposed, for Genoa, and thence for Venice, to both which governments he renewed his proposals without success, while his brother Bartholomew met with the same fortune in England. During the next season he visited Spain for the first time, under circumstances not unworthy of mention. A stranger, on foot, it is said, in humble guise, but of a distinguished air, accompanied by a small boy, stopped at the gate of an old Franciscan convent, near the sea-port Palos, and asked of the porter a little bread and water for his child. While receiving this humble refreshment, the prior of the convent, Juan Perez, happening to pass by, was struck with the stranger's appearance, entered into conversation with him, and soon learned the particulars of his story. It was Columbus and his son. The prior was still more interested in the eloquent explanation which the former gave of his theory. He detained him as his guest, therefore, and sent for a learned physician of Palos to converse farther with him. He, too, was delighted with Columbus; and so entirely convinced by his reasoning, that he pressed him to introduce himself immediately at court, and gave him a letter to the queen's confessor, Talavera, an intimate friend of his, and a man of great influence with the royal family. The good prior, meanwhile, took charge of the young Diego, the wife of Columbus being at this time deceased.

Columbus entered the city of Cordova in the spring of 1486, at a period when the whole chivalry of Spain was gathering together there for a final campaign against the Moors. This circumstance was unpardonable; and dress-

ed and introduced as he was, he could not even obtain an audience of the king or queen. Both of them soon left the city, and Columbus, too poor to follow them, resumed his old business of map-making. Meanwhile, however, he not only found leisure to form a new connexion with a lady of whom he became enamored, but he obtained the patronage of the archbishop of Toledo, by whom he finally procured an introduction at court. Columbus modestly, but eloquently, explained his project to the king, and the result was left to the decision of a council of learned men at Salamanca. Before them the navigator accordingly appeared, not daunted or dispirited, but with an elevated demeanor, an air of authority, a firm voice and a kindling eye. Some of them were interested warmly in his favor; but the majority decided against, and even ridiculed and reproached him. The objections made to his theory are curious illustrations of the state of science at that period. His clear and sound philosophy was overwhelmed by the writings of saints. Lactantius was quoted to prove that the antipodes are an inconceivable absurdity inasmuch as people cannot walk with their heels up and their heads down, nor trees grow, nor rain and hail fall upward. To say that there were inhabited lands on the opposite side of the earth, would imply too that there were nations not descended from Adam, it being impossible for men to pass the intervening ocean. Besides, the heavens were compared in Scripture to a tent, and the inference was that the earth underneath was flat. And then, should a ship ever reach Asia by sailing westward, it was clear as daylight, they said, that he could never get back again; for the rotundity of the globe would make the return-voyage altogether an up-hill cruise.

But the king not considering this opinion of the council decisive, Columbus was induced to linger about the court for nearly seven years, (while the war lasted,) when he returned to the old convent of Palos, resolved upon leaving the country forever. But here he was again befriended by the good prior and the physician, the former of whom insisted on writing to queen Isabella. This measure was adopted; and Columbus soon after re-

ceived an invitation to attend court, with a present of about \$200, wherewith to bear his travelling expenses, improve his dress, and provide himself a mule for the journey. All this was done promptly, and Columbus appeared before Ferdinand and Isabella. His proposals were heard with attention, but his terms being considered unsatisfactory and he refusing any concession of what he considered his dignity, the interview ended with disgust upon his part, and he immediately turned his back upon the court, once more determined to abandon it forever. He had gone about two leagues from Granada, when he was overtaken and summoned back by a courier of the queen, who, upon better reflection and at the instance of a warm patron of Columbus, had determined in his favor. An arrangement was now readily effected, executed April 17, 1492, by which Columbus and his successors forever were to hold the office of Admiral in the countries to be discovered; should reserve to himself a tenth part of the wealth; and *might* contribute an eighth of the expense of outfits. An order was issued for the preparation of two vessels at Palos; and for that port, the weary but successful adventurer, now in the fifty-sixth year of his age, once more started on the ensuing sixteenth of May.

Nearly three months were consumed in preparing the expedition now determined on, owing in a large degree to its unpopularity; nor was it until early in the morning of August 3d, that Columbus set sail, after solemn religious ceremonies, with his three small vessels, and 120 men. He had drawn an improved map of the world, in which Japan, the Cipango of Marco Polo, was nearly in the real situation of Florida. The first land made by the little squadron was the Canary Islands, where various circumstances detained them over three weeks. Other difficulties awaited him in the fears of his crew, many of the most rugged of whom broke into loud lamentations upon losing sight of the islands, and launching forth into an unknown ocean. Others became mutinous after the voyage had continued some weeks. But Columbus was not to be turned from his purpose. He kept a serene countenance on all occasions; and soothed, stimu-

lated, and threatened his ignorant and superstitious crew, as they occasionally required it. He sustained their hopes also by directing their attention from time to time, to large patches of weeds drifting on the water, from the west; to land-birds, whales, shore-fish, and every other appearance of a neighboring continent or island. On the 25th of September, as two of the vessels were sailing gently together side by side, Columbus was startled by a shout from the Pinta, and looking up he beheld Pinzon, the captain of that caravel, mounted on the stern of his vessel, and crying with a loud voice, 'Land! Land! Senor, I claim my reward!' (a pension of thirty crowns promised by the sovereign, to the first who should see land.) He pointed at the same time to the southwest, where there was indeed an appearance of land at a great distance. The enthusiasm raised by this incident was unbounded. Columbus fell upon his knees and returned thanks to God; and Pinzon repeated the *Gloria in Excelsis** in which he was loudly joined by the crews of both vessels. The light of the next morning, however, put an end to their hopes, for the fancied coast, which was nothing more than an evening cloud, vanished during the night. They were now dejected and mutinous again. But the signs of approaching land soon became too numerous and plain to be mistaken. The evening of October 11th, after the mariners of the admiral's ship had sung the vesper hymn to the Virgin, as usual, he collected them together, addressed them impressively, assured them that they should make land that very night, and promised a velvet doublet, in addition to the king's pension, to whomsoever should make the discovery.

Not an eye was closed that night, on board either of the vessels. All was enthusiastic expectation. As the evening darkened, Columbus himself took his station upon the top of the castle or cabin on the high poop of his vessel, and there maintained hour after hour an anxious and incessant watch. Suddenly, about 10 o'clock, he thought he beheld a light glimmering at a distance. Distrusting the eagerness of his own hopes, he called one of his

* Glory in the Highest.

friends, and demanded of him whether he saw a light in that direction; the latter replied in the affirmative; but Columbus, determined to be well satisfied, called another, and made the same inquiry. Before this third person could ascend the round-house, however, the light had disappeared, though it was seen once or twice afterwards in sudden and transient gleams, borne to and fro upon the shore. They continued their course until two in the morning, when a gun from the Pinta, the best sailer of the squadron, gave the joyful signal of land, which could now be clearly seen about six miles distant. It was discovered by a common mariner, but the reward was afterwards adjudged to the admiral for having previously perceived the light. The vessels now lay to, and waited for day-break.

That hour soon came, though slowly to those who awaited it, and a new and beautiful scene unveiled itself before the eyes of the voyagers. A long island was before them, covered with splendid verdure, spotted with magnificent trees like a continual orchard, sending out fresh sweet odors upon the gale, and surrounded by a calm sea of transparent clearness. Columbus entered his own boat, richly attired in scarlet, with the standard of Spain in his hand; while Pinzon and his brother, the commanders of the two caravels, put off in company in their boats, each bearing the banner of the enterprise emblazoned with a green cross, and having on each side the initials of the two Castilian monarchs. No sooner did they land than Columbus threw himself upon his knees, kissed the earth, and with tears of gratitude returned thanks to Heaven. The whole company followed his example. He then took solemn possession of the soil in the name of the king and queen, named the island San Salvador, and called upon all present to acknowledge his own authority as admiral. The feelings of the crew on landing, burst forth in the most extravagant transports. They pressed about the admiral, embraced him, kissed his hands, and implored his forgiveness for all the trouble they had caused him. The natives of the island, meanwhile, recovering from the terror which the first appearance of the Spaniards and their vessels had occasioned, gradually and silently drew nearer

to them, and gazed at the persons and proceedings of the new-comers with looks of profound awe, and with signs of adoration. Finding themselves unharmed, they continued to advance, and examine the hands, beards, and faces of the Spaniards more closely, Columbus treating them with a benignity, which soon won their entire confidence. The colored caps, glass beads, and hawk bells, which he distributed among them, they received as inestimable gifts, hanging the beads on their necks, and leaping with joy at the sound of the bells. The shore was again thronged with them the next morning. Fearless of the ships, which had at first seemed to them monsters of the deep, numbers of them came swimming off towards them; and others embarked in long light canoes, bailed with calabashes, and dexterously managed with paddles. Anything and everything, even fragments of glass, they received from the Spaniards as divine gifts, and cheerfully gave particles of their own in return; among other things, parrots, large balls of cotton-yarn and cakes of a kind of bread called cassava, made of a great root. One of them was at another time detained on board the admiral's vessel, for the purpose of conciliating him and his countrymen, though somewhat against his own will. Columbus put a colored cap on his head, strings of green beads around his arms, and hawk bells in his ears; and then dismissed him to return to the shore, and be surrounded and admired by his countrymen. After this, Columbus continued his cruise, and discovered the Bahama isles and the island of Cuba, delighted to enthusiasm, as his crew also were, with the rich and glowing scenery, the verdure, the perfume, the music of innumerable birds, the glancing light from the scales of many colored myriad fish in the clear water, the massy magnificence of the forests, and the simplicity and gentleness of the natives; only one of the habits of these people surprised them. Several of them were seen going about with fire-brands in their hands, and certain dried herbs, which they rolled up in a leaf, and lighting one end, put the other in their mouth and puffed out the smoke. This, it seems, was a tobacco, the name being originally given to the roll, and since transferred to the plant.

Off the island of Hispaniola, soon afterwards discovered and coasted by Columbus, he had the misfortune to be wrecked; and having before this parted company with one of the two caravels he was obliged to establish himself and his crew for some time upon the shore, where the natives treated them with all possible kindness. The sailors became so fond indeed, of the romantic and easy life which they passed in this beautiful island, with these happy people, that a large number of them volunteered to settle there while Columbus should return to Europe. This proposal was finally agreed upon; a fort was built of the wrecked vessel; stocked with its guns, stores and ammunition; and manned by thirtyfive volunteers, among whom were a physician, a carpenter, caulker, cooper, tailor and gunner. Articles were also left for trade. Having made all these arrangements, and given very full instructions and advice, Columbus sailed from the island Jan. 6, 1493, on his voyage for Spain. Pinzon joined him soon afterwards. The most remarkable incident of the passage was a storm of more than two days' duration, and of such extreme violence, that the fate of the two vessels seemed for a time inevitable. In this extremity many were the vows made on board, of pilgrimages, watchings, processions and penitence. But the tempest grew more terrific; and the danger of the ship was augmented by the want of ballast causing her to roll and toss about at the swelling of the waves. The admiral partially remedied this evil by having all the empty casks on board filled with sea-water, this measure gave some relief; but Columbus had other and peculiar causes of anxiety, and above all the gloomy apprehension that with him and his comrades, the memory and the immortal glory which belonged to him would be lost forever. With this feeling, he hastily wrote a brief account of his voyage on parchment; sealed and directed it to the king and queen, with a promise superscribed of 1000 ducats to him who should bear it safely to their hands; then wrapped it in a waxed cloth, which he placed in the centre of a cake of wax; and inclosing the whole in a barrel, threw it into the sea. To insure his object, a copy inclosed in the same manner, was placed upon the

poop of his vessel. Happily, neither of these memorials was ever needed, for the storm abated towards evening, and early the next day, land was made among the Azores.

The little squadron arrived off the mouth of the Tagus on the 4th of March, and in this vicinity Columbus remained, till May 13th, the object of universal curiosity and of very general admiration and respect. Barges and boats of every kind, full of spectators and visitors, covered the bosom of the Tagus. All hung with wrapt attention on the story told by the voyagers, and gazed with unbounded wonder upon the Indians and the specimens of unknown plants and animals they had brought with them. Even the king invited the admiral to an interview, and though evidently mortified at his own want of an interest in his glorious expedition, treated him with the attention due to his high rank and his unsullied character. The latter was not long detained, however, in Portugal. He reembarked on the 13th of March, and entered the harbor of Palos, on the 18th, amid the ringing of bells, and the loud shouts of the whole populace of that neighborhood. The fame of his discovery had resounded over all Spain; and wherever he passed on his way to the royal residence at Barcelona, the village-roads were lined with people, and the streets, windows and balconies of the large towns crowded with eager spectators, rending the air with their acclamations. His reception at Barcelona was still more magnificent. Escorted by large numbers of young courtiers and gallant cavaliers, and followed by an immense populace, he entered that noble city with almost the pomp and splendor of a Roman triumph. First in the march were paraded the Indians, painted and decorated in their native style. After these were carried various kinds of live parrots, stuffed birds and animals of unknown species, rare plants, and a rich display of Indian coronets, bracelets, pearls, gems and gold. Then came Columbus, with his splendid escort in long array around and behind him. Countless multitudes crowded the streets wherever they passed; the windows and balconies were filled, and even the roofs of the houses covered with spectators. In this manner Columbus approached the throne of his sovereign, and they

rose as he drew near. Kneeling down, he requested to kiss their hands; they then raised him in the most gracious manner, and ordered him to seat himself in their presence, and relate his adventures. This done, they sunk on their knees, wept with joy, and gave thanks to God; and the whole of the vast multitude present, with a common emotion, followed their example. Such was the reception of Columbus! Such the celebration of the most sublime discovery recorded in the annals of the world!

In the ensuing year, a second expedition was fitted out for Columbus, consisting of seventeen vessels and fifteen hundred men, including large numbers of young, noble and enthusiastic volunteers. They sailed before sunrise on the twentyfifth of September, 1493, from the Bay of Cadiz. In the evening of the twentysecond of November, after a winding cruise among several newly-discovered islands, they arrived at the harbor of the fort, named La Navidad, and anchored a league from the land. Here, impatient to know at least that the garrison were living, Columbus ordered a cannon to be fired; the report echoed along the shore, but there was no reply; no shout was heard; no light was seen; all was darkness and death-like silence. At midnight, a canoe was seen cautiously to approach the fleet. Those who paddled it, however, would not go on board even of the admiral's ship, until Columbus showed himself with a light at the side of the vessel. By their confused accounts, and by subsequent sources of information, it appeared that the unfortunate garrison had neglected the admiral's advice, and had suffered the consequences of their imprudence. The avarice of some, and the sensuality of others, occasioned quarrels with the natives, while jealousy and ambition embittered them against each other. The results were combinations, factions, brawls, war, and at last sudden destruction by the hands of the enraged and disgusted natives. Such was the history of the first European settlement in the new world.

But, discouraging as it was, it became necessary to undertake a second one; and for this purpose a site was selected upon the same island (Hispaniola) at a place where two rivers, a green and beautiful plain between them, and

a spacious harbor, gave promise of a more fortunate destiny. Here, too, the soil was fertile, the climate genial ; the trees were in leaf, the shrubs flowered, and the birds singing, though it was the middle of December. The settlement was immediately undertaken. An encampment was formed upon the plain ; the cattle, horses, stores, guns and everything on board the vessels was conveyed ashore ; streets and squares, gardens and orchards projected ; and the greatest diligence used in erecting a church, a storehouse, and residence for the admiral, of stone, beside a number of wooden and reed houses for the multitude at large. The greater part of the fleet, meanwhile, sailed for Spain on the 2d of February, 1494.

From this time commenced the troubles of Columbus. Many of his ardent followers were already disappointed in their extravagant expectations of wealth and glory ; and the same heat and moisture which fertilized the soil they had settled on, soon proved fatal to themselves. Provisions grew scarce, and labor became necessary ; but the cavaliers were both indolent and ill-humored, and thus controversy and jealousies arose between them and Columbus, which lasted during their and his whole life. To quiet them for a time, however, he undertook various exploring expeditions into the interior, and also voyages upon the neighboring seas. Jamaica was discovered, and that island and others already known were more thoroughly explored — the admiral himself sharing with his humblest companions, during all this time, the utmost of *their* privations and labors, in addition to his own peculiar and poignant anxieties, of which they could not even form a conception. Indeed so completely was he worn out, on his return in September to his new settlement, (named Isabella in honor of the Queen) as to be carried on shore at that place in a state of lethargy resembling death itself, deprived of sight, of memory and of all his faculties.

His history between this period and the ensuing spring may be passed over with the remark, that his brother Bartholomew arrived from Europe, meanwhile, to comfort and assist him in the difficulties which still beset him upon all sides. Not the least of these was a war with the

natives in the interior, and this had now advanced so far upon their part, early in March, 1795, that they were actually assembled in great force within two days' march of Isabella, and were preparing for a general and overwhelming assault upon the settlement. Columbus, now recovering from his sickness, determined to meet this movement in its first stages, though the whole force of his colony did not exceed two hundred infantry and twenty horse. These, however, were disciplined soldiers, cased in steel, covered with bucklers, and well armed with cross-bows, swords, lances, and heavy arquebusses, which were in those days used with rests, and sometimes mounted on wheels. They had twenty blood-hounds trained, strong, and terribly ferocious. Columbus began his march on the 24th of the month, and in two or three days came in sight of the enemy, collected in immense numbers at the place where St Jago has since been built. He immediately adopted the plan of attacking them in various directions, with a great din of drums and trumpets, and a deadly discharge of the infantry fire-arms from the covert of the trees. A charge was then made by the horse, with lance and sabre; while the blood-hounds let loose upon the naked savages, seized them by the throat, dragged them to the earth, and despatched them with a terrific violence. The Indians were panic-struck, and fled in all directions; nor was any resistance ever afterwards attempted by them, though thousands wandered and perished, from month to month, among the remote fastnesses and wilds of the island.

Meanwhile, intrigues, arising from jealousy and envy, were going on against Columbus in the court of Spain, to such an extent that the King and Queen thought proper to send out an agent, named Aguado, for the express purpose of ascertaining the truth or falsehood of the charges made against the Admiral. This agent arrived at Isabella in the fall of 1495; and Columbus, after enduring some insolence from him with astonishing dignity and calmness, resolved to return with him to Spain.—They sailed, accordingly, on the 10th of March, 1496, and arrived at Cadiz on the 11th of June. Columbus was at this time so dejected, that he had suffered his

beard to grow in the manner of Franciscan monks, and had clad himself in a garb fashioned and colored like theirs, girded only with a cord. Nor was he much animated by the indifferent reception which he met with, generally, among his misinformed and fickle countrymen.—His sovereigns, indeed, received him graciously, and even kindly ; and yet their exertions, situated as Spain then was, were insufficient to raise a third expedition for him until the spring of 1498. On the 30th of May in that year, still undiscouraged by all his disappointments and distresses, he sailed westward once more with a squadron of six vessels. In the course of this voyage he discovered Trinidad, and navigated the Gulf of Paria to a great extent, in the expectation of arriving at the end of what he considered a large island. Disappointed in this hope, worn down with labor and hardships, parched with fever, racked by gout—but not even now less sanguine than ever before—he returned to Isabella again, haggard, emaciated and almost blind. The troubles here, a series of factions and mutinies of the most insolent and violent character—the same which had constantly harassed his brother Bartholomew during his absence—now devolved upon him ; nor was it until the year 1490 that anything like harmony and order could be restored among the colonists.

At this time new disasters were ready to overwhelm him, for the intrigues against him in Spain had been resumed with increased bitterness. The effect was that a new agent, Don Francisco de Bobadilla,—an arrogant and unprincipled man, but entrusted nevertheless with large authority—was sent out to investigate the charges against the admiral, and to treat him according to the result, in a great degree as he might himself think proper. Bobadilla went far beyond Aguado in his insolence, for, he not only assumed absolute authority upon his arrival in the island, but proceeded to quiet all opposition, real or imaginary, by force ; summoned Columbus to appear before him ; put him and his brother in chains ; and in October of the same season sent them for trial to Spain, shackled like the vilest culprits, and amidst the scoffs and shouts of a servile and disorderly populace.

But neither the people nor the sovereigns of Spain were prepared for this step : and upon the arrival of Columbus on the shores of that kingdom in the condition just mentioned, a universal burst of indignation was excited. The king and queen, too, received the admiral, now liberated, with a kindness which overcame him more than all his calamities ; he threw himself upon his knees before them, and for some time could not utter a word for the violence of his tears and sobbings. But gracious as they were, and respectfully as they listened to his request that preparations might be made for a fourth expedition under his command, various obstacles stood in his way, as usual, not the least of which was probably a suppressed jealousy of the king. But an armament was at last completed, consisting of four small caravels and one hundred and fifty men : and the admiral, with his brother and son, leaving Cadiz once more, in May, 1502, arrived upon the shores of San Domingo about the last of June. Here, notwithstanding the apparent approach of a storm, Bobadilla's successor, the governor of the Colony, refused him even shelter for his vessels, a measure attributed by some writers to the circumstances that large numbers of the colonists were at this time the inveterate enemies of the admiral, and might be expected to treat him with violence. His excellent seamanship saved him, however, from the storm, terrible as it was ; while Bobadilla and many others of his worst enemies who had rashly embarked for Spain, regardless of his prediction, with all the ill-gotten wealth with which they loaded their vessels, were overwhelmed, and perished in the strife of the elements. After this, the admiral coasted along the shores of Honduras, the Musquito coast, and Costa Rica in the vain hope of discovering a strait between North and South America. Meanwhile, he discovered Porto-Bello, explored various sections of the main land, and attempted the formation of a settlement. Compelled after incredible exertions and sufferings to abandon these projects, he returned towards Jamaica ; nothing being now left of his sea-stores but a little oil, biscuit, and vinegar, while his men were obliged to labor incessantly at the pumps to keep their crazy vessel from sinking. In this condition, they

anchored among a cluster of isles south of Cuba, called the Queen's Garden, May 30th, 1503. Here, a sudden tempest came on at midnight, with such violence that, as Columbus himself writes, 'it seemed as if the world would dissolve.' The seas ran mountain high; and the winds dashed the vessels against each other in such a manner that, had darkness continued an hour longer, they must all have inevitably gone to the bottom. As it was, they were hardly able to continue the voyage eastward, their anchors being lost, the vessels 'bored as full of holes as a honey-comb,' and the leaks gaining upon them so that not only the pumps, but buckets and kettles, were incessantly used in bailing. Finally, on the coast of Jamaica, Columbus gave up the struggle; he ordered his crazy vessels to be run aground, within a bow-shot of the shore, and fastened together, side by side. They soon filled with water to the decks. Thatched cabins were then erected at the prows and stems, for the accommodation of the crews, and the wreck was placed in the best possible state for defence.

In this location Columbus remained about a year, at peace with the natives, but rebelled against and deserted by a large part of his soldiers, as well as reduced to extreme hazard of famine. He survived, however, with a small company of his men; and upon the 28th of June, 1504, they had the inexpressible satisfaction of leaving this memorable spot, in two vessels sent them by the governor of San Domingo. They arrived in that colony on the 13th of August; and there, for once, the unfortunate admiral, too humble and wretched to be any longer the object of envy, was received with the honor due to his distinguished character and services. He remained at this place until the 12th of September, when he commenced his last voyage to Spain; nor was it until nearly two months' tempestuous and perilous navigation, during which one of his two vessels was obliged to put back, that the other, shattered and crazy, anchored at last in the harbor of San Lucar. From this port, Columbus had himself immediately conveyed, feeble and worn out as he was, to Seville. Thenceforth, the rest which he now sought fled from his pursuit. His family affairs

were in confusion : ' If I desire to eat or sleep,' he writes, ' I have no resort but an inn, and for the most part have not wherewithal to pay my bill.' He was anxious, too, for the restoration of all the original honors of which he had been gradually deprived ; and he earnestly desired, on this and other accounts, to get to court. But this his illness made impossible ; and meanwhile his warm and constant patroness, the queen, died upon the 20th of November, 1504. He was able to spend months of attendance at court during the next season, but this was now unavailing : Ferdinand complimented him politely, but otherwise gave him neither encouragement or assistance.

Life was now drawing to a close, for he was once more confined to his bed by a severe illness, aggravated by his sorrows and disappointments. Ingratitude, the suspension of his honors, pecuniary embarrassments, defamation, anxiety for his own glory and for the welfare of the Spanish settlements in the west, all had their effect upon him, an effect too strong for a worn-out constitution to endure. Admonished of his approaching end, he made suitable preparations for it with resignation and with calmness. The property which he still owned he ordered to be distributed among relations, friends and servants ; so minutely remembering the smallest debts, that half a mark of silver was left to a poor Jew, who lived at the gate of Jewry in the city of Lisbon. These arrangements satisfactorily made, he turned his exclusive attention, earnestly but with composure, to the interest of his own soul : and having received the holy sacraments, and performed all the pious offices of a devout christian, he calmly breathed his last on the day of Ascension, May 20th, 1506, at the age of about seventy years. His last words were '*In manus tuas, Domine, commendo spiritum meum*'—' Into thy hands, O Lord, I commend my spirit.'

His body was deposited in the convent of St Francisco, and his obsequies were celebrated with funeral pomp at Valladolid. In 1513, his remains were transported to the Carthusian monastery of Las Cuevas, at Seville, where also those of his son Diego were deposited upon his death in 1526. Ten years after this, the bodies of

both father and son were removed to Hispaniola, and interred in the principal chapel of the cathedral of the city of San Domingo. But even here they did not rest in quiet—for when the Spanish section of the island just named was, in 1795, ceded by France to Spain, a strong solicitation was made by the latter that the ashes of the admiral might be exhumed and translated to Havana, in Cuba. The request was complied with; and the object carried into effect with a variety of solemn ceremonies not unworthy of mention. On the 20th of December, in the year last named, a large number of the most distinguished citizens and dignitaries of San Domingo assembled in the cathedral: and in their presence a small vault was opened above the chancel, in the principal wall on the right side of the high altar. Within were found the fragments of a leaden coffin, a number of bones, and a quantity of mould, evidently the remains of a human body. These were carefully collected, and put into a case of gilded lead, about half an ell in length and breadth, and a third in height, secured by an iron lock; the case was inclosed in a coffin covered with black velvet, and ornamented with lace and fringe of gold. The whole was then placed in a temporary tomb or mausoleum; on the following day, vigils and masses for the dead were solemnly chanted; and a funeral sermon delivered by the Archbishop of San Domingo. At four o'clock in the afternoon the coffin was conveyed to the ship destined for the transportation, with a civil, religious and military procession, banners wrapped in mourning, chants, responses and discharges of artillery. The key of the coffin was then formally delivered into the hands of the highest Spanish authority present, to be by him given to the governor of Havana. The transfer of the coffin itself was noticed by salutes, mourning-signals throughout the shipping of the harbor, and by all the other honors due to an admiral.

On the arrival of the ship at Havana, January 15, 1796, everything was conducted with the same deep feeling, and by similar circumstantial and solemn ceremonies. The remains were conveyed to land in the midst of a procession of three columns of feluccas and boats in

the royal service, and attended by distinguished citizens, and by a marine guard of honor, with mourning banners and muffled drums. On arriving at the mole, the remains were met by the governor, and were then conveyed, between files of soldiery which lined the streets, to the obelisk, in the place of arms; and thence, after great pomp and ceremonies of delivery, to the cathedral of the city. All these, and other, honors and ceremonies, say the historians of this great event, 'were attended by the ecclesiastical and secular dignitaries, the public bodies, and all the nobility and gentry of Havana, in proof of the high estimation and respectful remembrance in which they held the hero who had discovered the new world, and had been the first to plant the standard of the cross on that island. It is well observed by a recent distinguished biographer of Columbus, that when we read of the manner in which his remains were treated at San Domingo, after an interval of nearly three hundred years; the most illustrious men striving who should pay them most reverence; 'we cannot but reflect that it was from this very port he was carried off loaded with ignominious chains, blasted apparently in fame and fortune, and followed by the revilings of the rabble.' To that place, too, it might be added, the venerable and noble adventurer returned, upon his last voyage, to be refused admittance even to its harbor. 'Such honors, it is true, are nothing to the dead, nor can they atone to the heart, now dust and ashes, for all the wrongs and sorrows it may have suffered: but they speak volumes of comfort to the illustrious, yet slandered and persecuted being, encouraging them bravely to bear with present injuries, by showing them how true merit outlives all calumny, and receives its glorious reward in the admiration of after ages.'

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SCIENTIFIC TRACTS.

NUMBER XVI.

CHARACTER OF COLUMBUS.

It is natural, that an interest should be felt in the moral and intellectual character of a man, whose life occupies so large a space in the annals of the world as the life of Columbus. The discovery of America was a grand, a sublime event. It was an era in history. It was the opening of new oceans to commerce, of new continents to civilization and science, never to be again closed or lost. It not only waked up the activity of Spain and Portugal, the countries most immediately concerned in the act itself, but it sent a thrill to the heart of all Europe. A new impulse was thenceforth given to energy and to enterprise, wherever, in all countries and all climes, there was discontent to be quieted — poverty to be employed — avarice, ambition, the spirit of adventure, of science, of romance, of religion, to be gratified. Well, indeed — when the long-lost vessel of Columbus was entering the harbor of Palos on its voyage from the far west — well might the little community of that ancient and honored village, break forth into transports of joy, ringing the bells, shutting the shops, and suspending all business in the tumult and triumph of that memorable hour. Well might the progress of the admiral, from that place to the royal residence at Barcelona, resemble a Roman triumph in its splendor and pomp. Well might the tidings of his fame be spread far and wide 'by the communications of ambassadors, the correspondence of the learned, the negotiations of merchants, and the reports of travellers,' filling the whole civilized world with wonder and delight.

The character of the man who occasioned this universal excitement must needs be a subject of interest ; and the more so, when we come to know, that everything which he achieved, he achieved by the mere force of his character alone. He was in a great degree uneducated, — at least by any other care than his own, — for the life which he led, and the labors he performed. 'The son of an humble wool-comber of Genoa, he could place no reliance upon friends or fortune. Leisure, money, books, society, advice,' — everything was wanting to him in the outset, but the desire of knowledge, and the determination to obtain and to use it. More than this. He had positive obstacles to remove, and opposition to overcome, at every step of his progress, the very perusal of which is appalling to the reader of this age. The science and the ignorance of his times, the religion of the priestcraft and the superstitions of the people, the indifference and indolence of monarchs, and the envy and jealousy of all subordinate authorities, — these were among the least of his difficulties. Incredible labors were to be performed, privations to be endured, mutiny and faction, disappointment, danger, sickness, contempt, suspicion, insult, everything but death, and that despair, which to the unconquerable will of Columbus, was impossible. But he triumphed at last, and in the glory of that triumph, well may the memory of his woes and his wrongs be lost.

And yet it should not be lost. A lesson is to be gathered from them, not to be forgotten. And this lesson applies to all circumstances and conditions of men. Few, indeed, are called upon to do or to endure like Columbus, as still fewer can expect his reward. But in the sphere of the humblest man in society, there always is or should be some honorable and honest purpose in view ; and difficulties are to be encountered, and success obtained, not precisely of the same nature, but yet by the discipline and the exertion of the same common faculties. That this discipline and this exertion were the causes of his success, instead of extraordinary genius, as that vague word seems to be generally understood, — and in direct opposition has been seen to all other accidental resources — we shall endeavor to illustrate in the course of the following sketch.

It is worthy of special observation, in the first place, how early in life Columbus, though both unadvised and unaided, commenced the labor of *his own* education. Some opportunities were given him by his father, it is true, as it very rarely happens that such are not given : but these were in themselves inconsiderable, and it was *his* merit, of course, that he made the most and the best of them. He was not content with studying whatever books might be placed in his hands, though he did undoubtedly study them, such as they were, until he thoroughly understood them. But he learned from them that other knowledge was to be gained ; and so desire was excited ; effort was made to gratify and to satisfy it ; and this very desire, and this very effort, whether successful or not at the time, — and they almost always are so, at some time or other, — were still of essential value to his intellect and character. They encouraged a love of knowledge, that once awakened, never again slept. They brought upon him the necessity of reflection, and of close and constant observation of men and things, to answer the purpose of libraries and teachers ; of the entire application of all his faculties to everything that was — for the want of things that were not — within his reach. Thus was he confirmed in habits of deep thought, of industry, of thoroughness, of independence, intellectual and moral : and thus, as in thousands of other cases, was the foundation slowly but firmly laid for a life and a character, which have excited the admiration and astonishment of the world.

He neglected nothing which could be of service to him, however trifling ; and in nothing which he once undertook, and which, of course, he considered worth undertaking, did he stop short of such perfection as his means permitted. He wrote so elegant a hand, for instance, in his boyhood, that those who possessed some of his manuscript afterwards, were of opinion that he might have earned his livelihood by it alone. He paid a very strict attention to geography, astronomy, (then, astrology, however,) and to every other study necessary in the art of navigation ; for upon *this* all his desires and aspirations were bent from the moment he could appreciate the cu-

rious and adventurous spirit of his age. The labor which he spent upon the construction of maps and charts, in particular, may be inferred from the fact that he supported himself and his family for several years in Lisbon, by this very art; and on two or three other occasions during his long and eventful life, he resorted to the same resource. This skill and science he may have acquired, to a small extent, during the short period which he passed at school. But there he could have learned only the rudiments. He must have matured and multiplied them in his mind, as well as acquired the necessary manual dexterity, by devoting to these pursuits the leisure moments of his naval life in the Mediterranean, few and far between as they certainly were. He was fortunate, we have no right to say *sagacious*, enough to marry at Lisbon the daughter of a celebrated Italian voyager, whose plans, projects and documents constituted, with the explanations of his wife and her mother, both the recreation and labor of years. He embraced every occasion, meanwhile, to obtain information from every living source within his reach. He went to reside upon the newly discovered island of Porto Santo, for a time, that he might be in the way of the African navigators, who touched and sometimes tarried there on their voyages to and fro.

How rare, and how meritorious accordingly, was a skill like that of Columbus in the construction of charts, is evident from the distinction which Mauro, an Italian friar, obtained, from having projected a universal map, considered the most accurate of the time: a fac-simile of which map is now deposited in the British Museum at London. The Venetians struck a medal in honor of Mauro, on which they entitled him the *Incomparabile Cosmographer*. Americus Vesputius, from whom this continent has derived its name, paid 130 ducats, equivalent to 555 dollars of our coin, for a map of sea and land, made by Gabriel de Valseca, in 1439.

Nor did these attainments alone occupy the entire time of Columbus. The idea of his theory of the undiscovered western world, which must have occurred to him early in the course of his geographical reading, never

ceased from that time to be the subject of his thoughts, and the great object of his life. To digest and to substantiate it, even to his own satisfaction, must have cost him both reflection and research enough to be exclusively the employment of any man. The evidences of the former, furnished by his theory itself, and by the manner in which he sustained it, need not be enlarged upon. But it will be found, too, that situated as he now was and ever had been, — with the necessity, especially, of earning his daily bread by his daily labor, — he had carefully examined the best of the extant literature of his age upon the subject. He delved into the old and voluminous productions of Aristotle, Seneca, Pliny and Strabo, to prove that the ‘ocean surrounds the earth,’ or that ‘one might pass from Cadiz to the Indies in a few days.’ He corresponded with a learned doctor in Italy, and from him obtained a knowledge of the narratives of Mandeville and Marco Polo; all to corroborate the idea that Asia, or as he always termed it, India, stretched so far to the east as to occupy a greater part of the unexplored space, and to leave therefore but a comparatively narrow breadth of ocean to traverse on his way to the westward. Thus, step by step, year by year, was his theory established. And meanwhile he was personally deriving information from mariners, pilots, adventurers, even from the ignorant inhabitants of Porto Santo — among whom, no doubt, daily

———The wonder grew,
That one small head could carry all he knew.

He ascertained from one individual, that at the distance of 450 leagues to the west of Cape St Vincent, he had picked up a piece of carved wood, evidently not wrought with an iron instrument. Facts of the same nature were communicated to him by his brother-in-law, a navigator of some note. He had heard from the king of Portugal, that immense reeds had floated to some of the islands from the west; in the description of which he was prepared to recognise the large reeds described by Ptolemy as growing in India. He heard also of the trunks of huge pine trees, and of the bodies of two dead men cast

upon the island of Flores; and a mariner of Port St Mary told him, that in the course of a voyage to Ireland, he had seen land on 'the outer side,' which the ship's crew took for the extreme part of 'Tartary. Nor is it to be doubted that useful suggestions might accrue to a mind like that of Columbus, even from the prevalent rumors concerning the fancied islands of St Branden, the Seven Cities, and various other fables of a similar nature. All these things, at all events, were carefully noted among his memoranda; and trifling as they may appear at the present day, they were probably important as they were novel and rare then; and they certainly indicate, at least, the inquisitiveness and the energy of the indefatigable theorist. And thus, again, was the humble and poor day-laborer acquiring the confidence, and drawing together the knowledge, from all the ends of the earth, which were to be his guide and support through life, and to be the foundation of an imperishable fame.

Nor was it mere knowledge or mere discipline of the mind, or mere moral habits of value, which he had thus far acquired. As much as he had studied and learned, he was the very reverse of a simply sedentary or speculative man. On the other hand, he was eminently a practical and an active man. In the naval science of the Mediterranean, he had inured himself to bodily hardships, privations and exertions for many years; nor was he now situated to be free from them. But, however such a man might be situated, he could not be without resources for any undertaking. Whatever were his manual employments, no time was lost. Without leisure and without books — conversation in society, and reflection in solitude were made constantly subservient to the one great object. And thus — it is well worth observing — was he not only gaining that science and that power of mind which are or should be the ordinary results of the labors of a mere scholar; but he was gaining them by a study of human nature and human life, in himself and in all around him. Here he acquired the facility of reading the character and of managing the passions of men, which was so indispensable to his success in after-life; and without which no man, however learned or ingenious, is

fitted for the conduct of business, and especially of business upon a large scale. Even industry and energy, without self-command and command over others, will only suffice for a man so long as he labors by himself. If he would set on foot and sustain great plans, he must know how to illuminate or at least to control other minds, to interest other hearts, and to employ other hands, than his own.

We have attended to the self-command which was a trait in the character of Columbus. It was a very important one, too; for as no quality is so essentially necessary to an influence over others, so no individual ever had more occasion or more need, perhaps, for its exercise than Columbus. It was self-denial in temptation, self-possession in danger, self-respect and self-confidence in ignominy and disappointment, magnanimity in resentment, and in every emergency, in a word, coolness and fortitude. All these were in him, as indeed they are generally, but various manifestations of the same great principle of self-control, variously exercised by the different occasions of life. It is true that one temptation may be stronger in a man's mind than another — avarice than ambition, for example — or mere appetite than any passion; but it is also true that the same power which will enable himself completely to control the one, will enable him to check or to compromise with the other.

The first interview of Columbus with Aguado, the Spanish agent sent out to San Domingo, by the influence of his enemies, to investigate certain malicious and insolent charges brought against him, is a fine illustration of the foregoing remarks. Entrusted as he had been and deserved to be, in the first instance, with high honors and almost exclusive and supreme authority in the west, the mere appointment of a petty functionary to exercise even a 'brief authority' over him — with whatever decency or dignity it might have been done, had the functionary been anything like a gentleman, — would have been galling enough to a man of far less spirit than Columbus. But Aguado, a vulgar and weak character, was puffed up by his temporary power. He interfered with public affairs on his first arrival in the colony; ordered various

persons to be arrested ; called to account the officers appointed by the admiral ; and insulted his brother, who remained in command during the absence of Columbus himself. He then ordered his letter of credence to be proclaimed pompously by sound of trumpet, the vague and irresponsible wording of which was not the least of the provocations of the admiral — ‘ Cavaliers, Esquires, and other persons who by our orders are in the Indies, we sent to you Juan Aguado, our groom of the chambers, who will speak to you on our part ; we command you to give him faith and credit.’

Among a disorderly population, the report soon circulated that the downfall of Columbus was at hand, and that the grievances of the public were to be heard and redressed. Immediately, every culprit became an accuser ; for every man who had been punished was disposed to complain of it as oppression ; and all the other troubles which existed or had existed in the colony were imputed to the same source. Aguado, meanwhile, pretending to believe that Columbus, who was in the interior, purposed to avoid returning to the colony, affected to set out with a company of horse to go in quest of him. The latter, meanwhile, was hastening to Isabella to give him a meeting ; and Aguado, hearing of his approach, also returned there. A violent explosion was now generally expected (for the high sense which Columbus had of his services and dignity was well known,) and Aguado himself looked forward, it is said, ‘ with the ignorant audacity of a little mind to the result.’ But all were disappointed. Columbus received his rival, if a man could be called such, whom he so utterly and justly despised, with the most grave and punctilious courtesy ; only retorting upon him his own ostentatious ceremonial, by ordering the letter of credence to be again proclaimed by sound of trumpet in the presence of the wondering populace. He listened to it himself with solemn deference, and assured Aguedo of his readiness to acquiesce in whatever was the pleasure of his sovereigns. The advantages of this collected and dignified, though difficult course of conduct, are very obvious. He had to endure, indeed, the slurs of every dastard spirit in the

colony upon his courage. But he completely thwarted his mean rival. The latter had expected with some exultation to see him enraged or at least dispirited. He endeavored, in fact, a few months afterwards, to obtain from the public notaries present a prejudicial statement of the interview; but the good conduct of the admiral had been too marked to be disputed, and the testimonials were all highly in his favor.

During the absence of Columbus on his third voyage, Bobadilla was sent out from Spain with an agency similar to that of Aguado. He was a man of some rank, but he was needy, passionate and ambitious: and he had already made up his opinions violently against the admiral. He considered his alleged cruelty entirely proved, therefore, when he saw the body of a Spaniard hanging upon a gibbet on either bank of the river San Domingo, as he sailed up. This and a hundred other charges were substantiated, during the day, by multitudes of people who came off in boats to see him, and to pay court to him, while they revenged themselves by some accusation against Columbus. On landing, he assumed supreme authority at once, and called upon Don Diego, the brother of Columbus, (himself absent,) to submit to him. This he refused to do until he was satisfied of the right of Bobadilla to exercise this command; but the latter declined showing it, and contented himself with a few vulgar and blustering bravados. Not only Don Diego, he said, but the admiral himself should know whom they had to deal with. On the following day, as Diego still refused to give up certain prisoners whom he held confined by his brother's order, Bobadilla fell into a grievous passion; and having mustered a shouting and riotous mob about him by reading his commission, he proceeded forthwith to lead them against the prison. This was a small slight building, wholly incapable of resisting so tremendous a force, had there been any garrison in it — which there did not happen to be — or had the garrison been inclined to oppose this motley multitude with their own weapons. This not being the case, Bobadilla fell furiously upon the frail bolts and locks of the portal, and they gave way at the first shock; his zealous followers,

meanwhile, having been at the unnecessary trouble of applying ladders to the walls of the building in all directions, as if scaling a fortress. The prisoners were seized upon, and transferred to a prison of his own choice. He then insolently took up his residence in the house of Columbus; possessed himself of his arms, gold plate jewels, horses, books, letters, and other papers public and private, even of the most sacred nature; liquidated the demands of all who claimed any debt due from Columbus; and appropriated the residue, without the least ceremony, to his own benefit. He supported himself with the populace, meanwhile, first, by vilifying the admiral, and secondly, by proclaiming a general license for the term of twenty years, to seek for gold. He soon after summoned Columbus, who was in the country, to appear before him immediately.

The latter had heard of his measures, and he well knew the character of the man. He could scarcely yet believe, indeed, that such a character, if any, should be appointed to such an authority over himself, after all the sorrows and services which had worn him down nearly to the grave — a sufficient provocation alone, independently of the outrageous insults we have mentioned. The conduct of the admiral at this juncture is a true test of his character. Instantly on receiving the summons in the name of his sovereign, he started off unattended for San Domingo, while Bobadilla, in the meantime, was arming the city troops in the apprehension that Columbus was mustering an army among the Indians to resist him. He had just before this seized upon Don Diego, thrown him in irons, and confined him on board a caravel, without authority and without reason.

Columbus, purposely with no guards or retinue, now entered the city, amid the hostile preparation, bustle and bravado of Bobadilla. The latter, thus balked in his military ambition, avenged his own disappointment by giving instant orders for putting the admiral in irons and confining him in prison, — a measure which shocked even the enemies of the latter. No person could be induced to put the irons upon his person, in fact, until one of his own domestics, 'a graceless and shameless cook,' says

the historian Las Casas, 'with unwashed front, riveted the fetters upon his master with as much alacrity as though he were serving him with choice and savory viands.' 'I knew the fellow,' he adds, 'and I think his name was Espinosa.' The admiral being disposed of in this manner, there was no difficulty in proving him guilty of every charge of which he might be accused. He was found, accordingly, to have compelled gentlemen to labor in a case of public emergency, with their own hands; to have occasioned all manner of mutinies and seditions by his mismanagement, and then suppressed them by 'levying war against the government.' He had confined, starved, or otherwise punished various persons, all of whom were, of course, entirely innocent. Moreover, he had embezzled pearls, or at least pearls were found in his house: and the farther inference was, that the proceeds of all his voyages had been appropriated to his own benefit.

There can be no doubt that these base slanders were made a part of the suffering of Columbus during his confinement. The confinement itself he knew to be as much without cause as it was without authority. 'I make oath,' he writes at this time, 'that I do not know for what I am imprisoned,' — and again, — 'I was taken and thrown with two brothers into a ship, loaded with irons, with little clothing and much ill treatment, without being convicted or summoned by justice.' The latter step was subsequent to those mentioned already. Bobadilla, finding he had succeeded so well in his own abuse of Columbus, that insulting pasquinades were posted up at every corner, and horns blown by the mob in the neighborhood of the prison, felt secure in going still farther. Several vessels were now ready to sail for Spain, and he determined to put the admiral and his brothers on board of them, under charge of one Villejo. This man, who happened to be a gentleman, repaired to the prison, with a guard, to conduct his venerable prisoner to the shore. He found him still in chains, dejected and silent. He had long feared that he should fall a sacrifice to the vulgar and violent passions let loose around him; and he naturally looked to Villejo, when he entered, as his

executioner. 'Villejo,' said he mournfully, 'whither would you take me?' 'To the ship, your excellency, to embark,' replied the other. 'To embark!' replied the admiral earnestly: 'Villejo! do you speak the truth?' 'By the life of your excellency,' replied the officer, 'it is true!' The admiral now followed him almost with a cheerfulness, though obliged to endure, on his way to the shore, the scoffs and hoots of the assembled populace. Villejo treated him respectfully on the passage, and would even have taken off his chains; but this, with a noble dignity, he declined. 'No!' said he proudly, 'under the authority of my sovereigns, Bobadilla has put these chains upon me: I will wear them until *they* shall order them to be taken off, and I will preserve them afterwards as relics and memorials of the reward of my services.' It is affecting to know that he thought so much of this promise of his own, as to keep the chains ever after hanging in his cabinet, and to request that they might be buried with him when he died. It is abundantly evident, that he felt, on this occasion, as on many others, a great deal more than he expressed. His passions were strong, but his power over them was still stronger.

His life is full of illustrations of this self-control, and of the great advantages of it. In danger, for example, he not only secured the confidence or at least the respect of the people around him by his coolness, but he was perfectly possessed of his natural shrewdness of inventions, and thus frequently contrived plans of relief with as much readiness as he would have done in his closet at home. In one of his earliest Mediterranean voyages, he effected the design of his cruise against the remonstrances and threats of a mutinous crew, by apparently assenting to their wish to tack about — altering the point of the compass, and spreading all sail. The next morning they found themselves hundreds of miles from their expected destination, and were obliged to submit to his management for the rest of the voyage. So, in the first voyage over the Atlantic, when his ignorant crew were frightened by every new phenomenon they observed, he was invariably prepared to quiet them. He kept two reckonings during this voyage, in one of which, open to

general inspection, some leagues were daily subtracted from the ship's sailing, that the crews might be ignorant of the real distance they had advanced. With the same readiness he explained to them the explosions of the Teneriffe peaks—the variations of the needle—the sudden swells and calms of the ocean (the causes of some of which he did not himself understand)—while, on many of these occasions, his fanatical and frightened companions were muttering threats, in his hearing, of despatching him with violent hands. Another memorable instance of his coolness occurred on the return voyage, when, amidst the roar of a terrific storm—while the ocean foamed over his ship, and the mariners lay prostrate around him, trembling, praying, and buried in tears—he found leisure to write an account of his voyage and discovery. This he sealed, directed it to his sovereigns, and superscribed a promise of 1000 ducats to whomsoever should deliver it safe. He then wrapped it in a waxed cloth, which he placed in the centre of a cake of wax, and inclosing the whole in a barrel, threw it into the sea. Nor was this sufficient. For fear a single copy might be lost, he prepared another in precisely the same elaborate manner, to be placed in another situation; and all this, which he did for the satisfaction of his own ambition, and the good of his country, he had the sagacity to use as a means of quieting the fears of the seamen, under the pretext of having performed a solemn religious vow for the laying of the storm.

In another case, his astronomical science was the means of his safety. He, and a few of his crew who had not mutinied and deserted him, were confined on the desolate shores of the Island of Jamaica, while the natives around him would neither sell them food, nor suffer them to procure it. They were, in fact, in imminent danger of starvation, besides apprehending a still more dreaded hostility on the part of the natives. Columbus, knowing that there would be a total eclipse of the moon in three days, sent an Indian to summon all the chiefs of the neighborhood to a grand council, on the day of the eclipse. Having got them together, he gave them a solemn warning of the fate which awaited them, if they

refused to furnish him with provisions; as a confirmation of which he told them they would see the moon deprived of its light. Some of the Indians were alarmed at this; others scoffed; but all awaited the evening with great anxiety. A dark shadow began to steal slowly over the moon, as they stood watching it in silent awe, and they trembled at the sight. Their fears increased with the progress of the eclipse: and when a mysterious darkness finally covered the whole face of nature, there were no bounds to their terror. They hurried to the ships with whatever provisions were nearest; threw themselves at the feet of Columbus; implored him to intercede with his god; and promised thenceforth to bring him anything and everything which he wished. Columbus, telling them then he would do what he could, retired to his cabin, and shut himself in during the increase of the eclipse, while the forests and shores resounded all the while with the howling of the savages. At last, as the eclipse was about to diminish, he came forth, and gave them to understand that he would soon withdraw the darkness from the moon, in consideration of what they had promised. As more and more of the face of the bright planet now became visible, they were overwhelmed with joy and admiration; nor from that time forth did they cease to propitiate the friendship of Columbus, as a man peculiarly owned by the deity. This anecdote is given in proof of his presence of mind in great danger. It shows also to what an extent he had pursued his astronomical investigation, as he pursued everything else which he undertook; and how, indirectly as well as directly, sooner or later, almost all knowledge may become useful in the various emergencies of life. At all events, it can never be without value, if it does but inspire the self-confidence which is indispensable to self-possession.

Nor is it — or was it in the case of Columbus — of service only in emergencies. It was never absent, as the occasion of it never was, in his mind. It kept up, in the great continuous courses of events which distinguished his life, the universal dignity — the moderation — the magnanimity of his character. No individual, perhaps,

was ever more thoroughly tried, or more honorably acquitted, by adversity or by prosperity. He endured every hardship, privation, ignominy, disappointment, distress, desertion, ridicule and contempt; and he bore up against all, and triumphed over all, silently, slowly and alone, but completely and gloriously. But he had to triumph also over the strong temptations of flattery, of unbounded and magnificent success, of popular admiration, and of royal favor; and these were not the least of his trials. We have but to imagine him, as he frequently was, 'surrounded by doubt and danger; a foreigner among a jealous people; an unpopular commander in a mutinous island; distrusted and slighted by the government he was seeking to secure; and creating suspicion by his very services.' To these circumstances must be added his loneliness, the hardships of a wandering and perilous life, and the extreme physical sickness and suffering which several times brought him to the brink of the grave.

Is not such a man prepared, and does he not deserve to relish, whenever and wherever they may meet him, the luxury of indolence and plenty, the ostentation of success, the pride of popularity, the opportunity of safe revenge, the sweetness of adulation, and the glory of fame? In the very shackles of the culprit, then, as he leaves one shore of the Atlantic, hooted at by the mob, let him be landed upon the other. There let his chains fall; let his purse be filled, his success acknowledged, his innocence proved, his favor solicited, his enemies and his rivals humbled at his feet, his person followed from town to town, over all Spain, with the splendor of noble processions, and the welcoming shouts of admiring multitudes, while his glory sounded throughout the civilized earth as the Discoverer of a new world. All this affected not the equanimity of Columbus. He forgave his enemies the moment they were prostrate at his feet; and humbled himself before Heaven, for his success, as the poor instrument of its will.

And yet, as we have intimated, there are abundant proofs that the moderation, the courage, the fortitude of Columbus were not founded upon his want of feeling. On the other hand, his natural passions were uncommonly

strong. Instances are not wanting to show that he was even *passionate*, in the vulgar sense of the term, for he could not always forbear punishing excessive insolence with his own hand. But these few cases only suffice to show what the 'angry temper of his soul' *might* have been, had it been habitually or even frequently left to its own nature.

But he gave free course, on the other hand, to all generous and tender emotions. In the first place, he was enthusiastically religious. When he looked back in age upon the early career which, hard and painful as it had been, seemed precisely calculated for his final success, he regarded himself with a solemn and humble awe as the appointed instrument of God. His theory was to him a gift of inspiration. He read his contemplated discovery ere it was yet attempted, as foretold in holy writ, and shadowed forth darkly in the mystic revelations of the prophets. It was to be the triumphant consummation of his enterprise, that the ends of the earth should be brought together, and all nations and tongues and languages united under the banner of the Saviour. A chief argument, indeed, by which he persuaded the sovereigns of Spain to countenance his undertaking, was founded upon the prospect of subduing, through the medium of Christianity, the vast and magnificent empire of the Grand Khan, and the opulent isles beyond, which he expected to arrive at in his western voyage. But he went farther than this, even then. Kindling with the anticipation of boundless wealth, to be realized by his discoveries, he suggested that all the 'pearl and barbaric gold' thus obtained should be devoted 'to rescuing the holy sepulchre of Jerusalem from the power of the infidels.' This singular project ever after continued to be a grand object of his ambition. In the flush of fortune and glory which succeeded his first arrival from the west, he even made a vow to furnish within seven years an army of 1000 horse and 50,000 foot for this favorite purpose, and a similar force within the five following years. In the will which he executed in 1498, he made provisions of the same nature. Whoever might inherit his estate was solemnly enjoined to vest, from time to time, as much

money as he could spare, in stock, in the bank of St George at Genoa, to form a permanent fund, subservient at any future time to the king's conquest of Jerusalem. If the king should not undertake it, *he* was to set on foot a crusade at his own charge and risk.

It is not strange, that a man of this ardent temperament should yield to many of the prevalent superstitions of the age, less characteristic of his own genius. During a tremendous storm which occurred upon his first voyage, some of the crew, by his orders, vowed that in case a certain lot fell upon him, he would make a pilgrimage to a certain saint, bearing a waxed taper of five pounds' weight. The admiral drew the lot, and from that moment considered himself a pilgrim bound to perform the vow. He undertook another pilgrimage also, a solemn mass, and a vigil. He speaks of a certain movement of the sea afterwards as providentially ordered to allay the clamors of his crew, like a similar interposition of old, in favor of Moses.

The suppression of a mutiny is attributed to the same cause; and he himself records an instance of what he considered a supernatural visitation. He was sick and dejected, he says, and had almost abandoned himself to despair, when he heard a voice calling to him, 'O man of little faith! be not cast down; fear nothing; I will provide for thee. The seven years of the term of gold are not yet expired, (all allusions to the vow of the holy sepulchres,) and in that and all other things I will take care of thee.' On that very day, he adds, he received intelligence of the discovery of a large tract of country rich in mines. Again, he writes to the king and queen, that the Indians of Cariari, on the coast of Jamaica, were great enchanters; as also that two of their girls, who had visited his ship, had concealed magic powers upon their persons. This was the belief also of his mariners, it seems; and the origin of it was, that some of them had taken out pen, ink and paper to write in presence of the Indians, who, mistaking the process for a necromantic spell, had themselves scattered a fragrant powder in the air to counteract it.

The most obvious explanation of a trait in this great

man, which would now be considered a weakness, is in the universal spirit of the age in which, and the people among whom, he lived. He might go beyond them in knowledge or in enterprise; but the science which undermines superstition had been less a subject of his attention, while his susceptible temperament exposed him more than most men to the influence of mere impression, individual and contagious. We must consider also the extraordinary circumstances under which he encountered these impressions, — on the shores of an undiscovered world, where everything on land and sea, animate and inanimate, wore in itself the appearance of novelty and of mystery, independently of the excited expectation of the individuals concerned. Ill health, and a shattered nervous system, are circumstances also of this case. But above all, we should estimate the influence upon the mind of Columbus, of his own early, favorite, deep-fixed theory, with the ten thousand hopes, recollections and reveries so intimately, so constantly associated with his intense and ceaseless study of the subject. It is no wonder, then, that his imagination partook of the almost supernatural excitement of every other faculty of his soul: it would have been wonderful if it had not.

It is a matter of strong interest, under these circumstances, to observe the enthusiasm of his speculations; and how closely this quality follows upon his shrewdness and his science, frequently passing and outstripping them, though seldom with any jostling or confusion. In exploring, for the first time, the great gulf of Paria, for example, he formed one of his simple and grand conclusions from the strict rules of science, and the laws and the phenomena of nature. The vast body of fresh water which he found rushing into that gulf, could not be produced by an island or by islands. It must be some mighty river, he believed, which had wandered through a great extent of country, collecting its many streams. The land, therefore, must be a continent. The various tracts he had touched in various places, must have some connexion with each other. The coast of Paria, off Margarita, must extend far westward; and the land seen from Trinidad far southward, into an unknown tract of ocean. Thus far he argued like Colum-

bus, upon his own reason and knowledge. But he would penetrate *more* thoroughly these regions of mystery, though guided only by the dim lights of the science of his age. 'This must be, he continued, an extension of the Asiatic continent. Of course, the greater part of the globe is firm land : and in this conclusion he found himself supported by Aristotle, Seneca, and various saints and cardinals — not to lay stress upon the apocryphal assertion of Esdras, that of seven parts of the earth six are dry land. Here, then, was a beautiful and fertile country, wide-spread under the most benignant skies, rich with the 'jewels of the mine,' free to be explored, appropriated, and above all christianized, by any nation capable of doing it. Columbus was borne away by the fervor of his hopes. 'May it please our Lord,' he writes to his sovereigns, 'to give long life and health to your highnesses, that you may prosecute this so noble enterprise, in which, methinks, God will receive great service, Spain vast increase of grandeur, and all Christians much consolation and delight, since the name of our Saviour will be divulged throughout these lands.'

His reveries go far beyond this. He collected an astonishing variety of phenomena, going to support, as he thought, a new theory of the earth, according to which, instead of being spherical, it was pear-shaped. The protuberant and tapering part he located in the interior of his new continent, and upon the edge of this swelling of the earth he had already arrived. Hence, certain variations of the needle were singularly accounted for. Hence the climate of great heat and unwholesome air he had met with, arising, as he had told Peter Martyr, from his 'having ascended the back of the sea, as it were ascending a high mountain towards heaven.' And so, too, the altitude of the north star increased, and the circle it described appeared larger. And thus he explained the great superiority of the country, the air, and the people, in freshness and beauty, over others in the same latitude — such as those of Africa. He looked up confirmations of this opinion, as usual, in the ancient writers. And as to holy writ, he observed, that 'the sun, when God made it, was in the centre of the orient, or the first light was there ;' and that place could only be

here, where the ocean and the extreme part of India meet under the equinoctial line, and at the supposed prominence of the earth. This prominence he further supposed to be of great height, though its sides rose slowly and smoothly, the shores of Paria being situated on its remote borders. As one ascended, no doubt, the land would be found still more fertile, the scenery more beautiful, the air more serene and celestial. There, in a word, must be the original abode of our first parents, the terrestrial Paradise, and there must still be preserved its primitive and blissful delights, though accessible to mortal feet only by divine permission. Such was the strange mixture of speculation and science, of fancy and fact, suggested to the mind of Columbus by the current of fresh water rushing into the gulf of Paria, and springing, as he believed, from the tree of life in the garden of Eden !

We have made these remarks in the train of an observation upon the ardent temperament of Columbus, and to prove that his self-command never was owing to indifference of feeling. And how much is our estimate of his fortitude and his magnanimity enhanced, when we find that his worst misfortunes and his worst enemies came upon him in the full career of these splendid visions ; that they checked and shackled him while yet panting, within view, as he believed, of the consummation of his hopes, his happiness, and his glory. No wonder that, succeeding as far as he had succeeded, he should have been anxious for his own future fame, and unwilling that what he had already acquired should be lost to him in ignominy, or in oblivion. Hence the expedient he hit upon in the tempest, to preserve a memorial of his discovery, and the astonishing resolution with which he effected it, and the great relief it is known to have given him. So in a similar case on his return-voyage — ‘ I could have supported this evil fortune with less grief,’ he says, ‘ had my person alone been in jeopardy. But it was a cause of infinite sorrow and trouble to think, that after having been illuminated from on high with faith and certainty to undertake this enterprise ; after having victoriously achieved it ; and when on the point of convincing my opponents, and securing to your highness great

glory and vast increase of dominion, it should please the divine Majesty to defeat all by my death.'

It may be inferred from this simple expression of the feelings of Columbus, that he had the interest of his country, as well as his own honor, at heart; and there are other abundant proofs both of his patriotism and his loyalty during the whole course of his life. Nothing, as it has been truly said, can surpass the affecting earnestness of his own declaration to this effect — wrung from him, it should be added, by an ingratitude which must have stung him to the soul. — 'I have served their majesties,' says he, 'with as much zeal and diligence as if it had been to gain paradise; and if I have failed in anything, it has been because my knowledge and my powers went no further.' There can be no doubt of the entire truth of this statement, nor of the personal attachment which he cherished for Isabella, and the unbounded confidence he reposed in her magnanimity. 'May it please the Holy Trinity,' he says upon hearing of her last illness, 'to restore our sovereign queen to health: for by her everything will be adjusted which is now in confusion.' At the very moment he was thus writing, his benefactress was a corpse, and he heard of her death soon afterwards. 'Let me remind thee, my dear son Diego,' he writes upon that mournful occasion, 'let me remind thee of what is at present to be done. The principal is to commend affectionately, and with great devotion, the soul of the queen, our sovereign, to God. Her life was always catholic and holy, and prompt to all things in His holy service: for which reason we may rest assured that she is received into His glory, and beyond the cares of this rough and weary world. The next thing is, to watch and labor in all things for the service of our sovereign the king, and to endeavor to alleviate his grief.' Such was his enduring loyalty towards the monarch who was so ungratefully neglecting him — expressed, it should be observed, in a confidential and secret letter to his son. That Ferdinand was not ignorant, ultimately at least, of the services which the admiral had rendered him and his country, would appear from the monument which he ordered to be erected to his memory, and the motto engraved upon it, — **TO CASTILE AND LEON COLUMBUS GAVE**

A NEW WORLD. In this connexion should be noticed also the provisions which the admiral made for his native city, Genoa, as well as the injunction of loyalty, and faithful and zealous service, 'to the loss of life and estate,' which he left upon his heirs.

He made provision in this same will for the poor females of his family; ordering that a married person of his line, native of Genoa, should be respectably maintained there, that a domicile might be kept open for them. As early, indeed, as his first residence in Lisbon, while he was yet struggling to maintain his own household by his daily labor, we are told of his appropriating part of his scanty means to the succor of his aged father at Genoa, and to the education of his younger brothers. To these he continued the attachment through life; and between his own sons, the comfort and support of his declining years, he ardently cultivated a harmony of the same nature. 'To thy brother,' he writes to Fernando, 'conduct thyself as the elder brother should unto the younger. Thou hast no other, and I praise God that this is such a one as thou dost need. Ten brothers would not be too many for thee. Never have I found a better friend, to right or left, than my brothers.' These simple expressions, warm from the heart of Columbus, are as affecting as they are artless.

And such was his gratitude and his affection for all that ever served or loved him. The care of his seamen was as much upon his mind as the care of his children. 'It would have been more supportable,' he says in the case of the tempest alluded to above, 'had I not been accompanied by others who had been drawn on by my persuasion, and who might have turned back but for that.' On his very death-bed, and in the midst of personal distress, he was more solicitous that justice should be done to them than to himself. He wrote repeatedly to his sovereigns, urging the discharge of their arrearages; besides requesting his son, then at court, to exert himself in their behalf. 'They are poor,' said he, 'and it is now nearly three years since they left their homes. They have endured infinite toils and perils, and they bring invaluable tidings, for which their majesties ought to give thanks to God, and rejoice.' Several of these men had been among

the number of his enemies, and others of them he knew to be still disposed to do him harm rather than good.

Nor ought we to omit the uniform benevolence with which he treated the poor natives of the countries he discovered. And it is interesting to observe the effect it had upon them. On first landing upon the shores of Hispaniola, for example, his sailors saw a crowd of the Indians flying from them in terror. They pursued, and at last overtook a young and handsome female, and brought her off to the ships. The admiral soon soothed her terrors by his kindness. He had her clothed; made her presents of beads, brass rings, hawks' bells, and other trinkets; and sent her back safely to the shore, so pleased with his finery and his kindness that she would gladly have remained on board. On the following day, the admiral despatched nine men to look for the village to which this woman belonged. The natives met these men, to the number of 2000, approaching them with slow and trembling steps, and pausing often, their hands upon their heads, in token of profound reverence. Another multitude joined them soon afterwards — at the head of them was the husband of the female just mentioned. They brought her in triumph on their shoulders, and the husband was profuse in his gratitude for the civility with which she had been treated, and the magnificent presents bestowed upon her. The Indians, on becoming more familiar with the Spaniards, invited them to their houses, on the bank of a fine river in a beautiful valley; and set before them cassava, bread, fish, roots, and fruits of various kinds. Having ascertained that their guests were fond of parrots, they gave them great numbers of them already domesticated, and indeed offered everything else they possessed. These transactions were rumored over the neighboring country; and when Columbus was soon after wrecked upon the same coast, he experienced the benefit of his kindness. Well might Columbus say of such a people, as he does with a manifest pleasure — 'So loving so tractable, so peaceable are they, that I swear to your majesties there is not in the world a better nation, or a better land.' On every future occasion, to the last days of his life, he watched over the welfare of the Indians with the anxiety of a father. His final exertions at court

were in their behalf; and it gave him infinite distress, that the plans he had formed for their civilization and happiness were neglected and counteracted by his successors.

An illustrative remark of some interest, perhaps, may be made upon the extreme susceptibility of Columbus to the beauties of nature. 'As I arrived at this cape,' says he, 'there came off a fragrance so good and soft, of the flowers and trees of the land, that it was the sweetest thing in the world.' 'One could live there forever,' he observes of some quiet and delicious scene; and then Cuba first broke upon him like an elysium, — 'It is the most beautiful island,' he says, 'that eyes ever beheld.' On another occasion, the breeze was blowing from the shore after the usual evening shower; and it brought with it the sweetness of the land, the distant songs of the natives, and the sound of their rude music, as they were probably celebrating with their festive chants the arrival of the white men. So delightful were these things to Columbus, that having spent the whole night in enjoying them, he declared it had passed away like an hour.

Such was the character of Columbus — quite as extraordinary, on the whole, as his life. Indeed, we can scarcely refrain, after reviewing it, from sympathizing with him in his own solemn persuasion, that he was raised up, qualified, and supported by Divine Providence for the great destinies which he fulfilled. Had he never lived, however, undoubtedly this continent could not have remained long undiscovered. Still, the glory is his that he went far beyond his contemporaries, not in originating the theory only, but in fearlessly undertaking and victoriously completing the prosecution of its proof, in the face of every moral and physical opposition and obstacle, which it is possible to conceive. And how memorable is the lesson to be gathered from this glorious triumph of naked intellect and energy! How should it animate and elevate, in all countries and in all climes, the exertions, the hopes, the ambition of that vast portion of mankind, who are compelled by circumstances to be the artificers of their own fortune and their own fame!

SCIENTIFIC TRACTS.

NUMBER XVII.

THE PROPERTIES AND FUNCTIONS OF ORGANIZED BEINGS.

MATTER is of two kinds, organic and inorganic. To that which is arranged into a certain form, and endowed with a living principle, the term organized is applied. That which is not endowed with life is classed among the inorganic substances. All plants and animals come under the class of organized substances or beings. It is our object in the present tract to take a superficial survey of the vegetable and animal kingdoms, so far as it regards their *physical properties* and *organic functions*.

The history of organized beings, or anything that relates to them, must be of interest to us all: for from the first moment of our existence, we form an important link in the animal chain. The power of nature is no less manifested around us than within us. — We are surrounded by animals subject to the same wants, endowed with the same physical properties, and maintained by the same vital processes with ourselves, — at the same time, they are subject to our wills, and aid us in our enjoyments.

Vegetables as well as animals are endowed with an organized living principle, by which they are enabled to select their food, to change that food and apply it to their wants, and to produce fruit by which their species may be propagated.

They have a beginning and an end, or in other words, they are born, and after passing through various changes, and undergoing a limited existence, they die. If the

interesting inquiry was made — What is life, or what principle is that by which water is changed into a vegetable substance, or vegetables into animal? what principle is that which gives to bodies mobility or the power of motion, which enables different parts of the same body to cooperate for the purpose of producing a given effect, and which prepares them to maintain a fixed temperature in opposition to that by which they are surrounded? — we should answer, that this is the living principle, and that these were the properties by which we distinguished living organized beings.

We know not what life is of itself; but we know some of its properties or effects, and we at once pronounce that a living being or thing which has a certain assemblage of properties.

Plants, by means of small vessels situated in their roots, absorb or take up the moisture from the earth, and this after having passed through various vessels becomes a part of the plants. Some animals live entirely upon vegetables, yet these vegetables eventually become a part of the animal. Now this property which plants and animals have of changing foreign substances into a part of themselves, is a property belonging only to living things, and it is therefore called a *vital property*. Animals have the power of moving from one place to another in quest of food or pleasure by means of a particular apparatus which is subject to the will. Now this power properly belongs only to living beings, and this is also called a *vital property*. All animals and plants have the power, to a certain extent, of maintaining a fixed temperature in opposition to that by which they are surrounded. Thus the temperature of man never varies more than six degrees, although that of the atmosphere may vary a hundred or more. This property of resisting the action of cold or of producing heat, receives also the name of *vital property*. These properties are the effect or result of the living principle, and farther than its effects, we know not what life is. We all of us feel and see the effects and influence of the mental powers, but farther than its effects we know not what mind is. We all know that there is such a principle in the physical world as at-

traction or gravitation, but no one can tell what attraction is. We see one body attracted by or drawn towards another, and this is the effect of a certain cause to which we give the name of *attraction*. We cannot define it except by its results. So it is with life. We know not what life is, but we know what are the effects of that something which we call life.

There is a regular and gradual progress towards perfection in the organic world, beginning with the simple plant and passing up to men, and it forms a chain so perfect in all its parts, that it is almost impossible to describe one link without taking into connexion those with which it is united. It would seem easy at first sight to tell the difference between a plant and an animal, and yet to point out the exact difference between the most perfect plant and the most imperfect or least complicated animal, has been a task for the performance of which the greatest philosophers have almost acknowledged their entire incompetence. If we should ask how you knew a plant from an animal, what answer would you give? Perhaps you would say that animals have eyes and ears, and plants have not. It is true that most animals have these organs, but not all. Some animals are destitute of eyes, ears, brain, and even of a heart. You might say that animals require food, but plants require food as well as animals. Plants are organized, and possess the principle of life to a certain degree as well as animals; but the latter have some properties in addition to those that belong to plants. Animals have the power of *locomotion*, that is, the power of moving from place to place, but plants are destitute of this power. Plants have simple life as well as animals; but the latter have something added to life, which we call *instinct*. — All animals have desires; they determine, they act. — They eat at intervals, and their food requires time to digest; but plants receive nourishment instantly. Animals are to a certain extent capable of evading danger; they do this under the impulse of fear; but plants are subject to everything that moves. We may trace the whole organic chain from the simple plant up to man, and we shall find that there are certain physical properties belonging to all. We

have seen how nearly the simple plant resembles the most imperfect animal ; yet what a wonderful and manifest difference there is between the physical properties of the polypus (which belongs to the lowest order of animals) and man, the most perfect and complicated of all organized beings.

Each order of animals which fill up the space, has some one property as it advances towards man in addition to those possessed by the order below it.

Man, although he is placed entirely and absolutely distinct from the whole organic creation by his intellectual powers, by his knowledge of the principles of vice and virtue, by his moral accountability, and by his confidence of a still higher destiny than this life can afford ; yet he is subject to the same physical wants that distinguish the lowest order of animals. He requires food as well as they, and in both it must pass through a similar process before it can form a part of themselves. There must be a set of vessels to convey the fluids from one part of the body to another in both — one requires the influence of the atmospheric air as well as the other, and you can trace through all their organic functions a like similarity. It is these functions together with the organs that perform them, which we will now describe.

All organic substances require food for the nourishment and development of their various organs. Accordingly all are supplied with apparatus by which the food is taken and converted into its appropriate texture. Most plants receive their nourishment from the earth. This nourishment is taken up by vessels situated in their roots, and is conveyed by other vessels prepared for the purpose, to the extreme part of the leaves, where it undergoes the process of digestion or assimilation, and is converted into a substance fit for their growth. From the leaves the assimilated fluid is conveyed to all parts of the plant, and by appropriate organs is changed into a part of itself. If there is any excess or waste substance this is carried off from the plant by vessels prepared for that purpose. The arrangement of vessels in animals is precisely upon the same plan as in plants, only in the former they are more complex.

In the most perfect animals and in man, food after it is masticated or chewed, and mixed with saliva, which is secreted by glands situated around the mouth, passes into the stomach by means of a small tube, called the *oesophagus*. After it has arrived in the stomach, it is mixed with and acted upon by the *gastric juice*.

The gastric juice is a fluid which is secreted by the small vessels of the stomach. It has the property of preventing in a remarkable degree the process of putrefaction—and it not only prevents, but all substances however putrid they may be when taken into the stomach, are in a short time restored to a state of perfect sweetness. Meat is usually eaten when sweet, but fashion and the luxurious desire of having something new, or different from others, has been temptation enough for some even in civilized life to keep their venison as long as they could endure the smell. The inhabitants of some savage countries value their meat in proportion as it approaches putrefaction. The gastric juice possesses likewise wonderful solvent powers. — It is more powerful in this respect however in some animals than in others. — ‘The toughest meat and the hardest bones are digested in the stomach of a buzzard. The gastric juice of a dog will dissolve ivory. Not many years since the handles of several knives were found half digested in the stomach of a man who died in London in consequence of his hardihood in swallowing them.’* After the food has been reduced to a pulpy state in the stomach, it passes from it into the *duodenum*, or what may properly be called the second stomach, there to undergo other important changes. It is here mixed with bile, which is secreted by the liver, and with the pancreatic juice, which very nearly resembles saliva in its looks and properties, and is converted into a substance called *chyle*. The nutritious part of this chyle, or such as is fit to be converted into blood for the nourishment of the various parts of the body, is taken up by a set of small vessels, called *lacteals*, (from the color of the fluid which they convey being that of milk.) These small vessels empty their

* Good’s Study of Medicine.

contents into a tube or duct which leads directly to the blood vessels, where the chyle is mixed with and converted into blood. The blood is now conveyed to the heart, and this immediately contracting propels its contents into the lungs, where it undergoes important changes, which we shall presently describe.

All animals do not eat of the same kind of food. Some feed upon flesh, others upon vegetables, and others upon a mixture of both. Man is omnivorous. He can live either upon vegetables or flesh, and his stomach is accordingly adapted to that purpose. The formation of the stomach, and the kind of food which animals eat, seem to have a great influence over their manners and disposition. The lion, the tiger, the hyena, &c, live entirely upon animal food. — Their stomachs are small and short, their food is digested rapidly, and the cravings of their appetite necessarily create in them a ravenous and rapacious disposition. — Their cruelty, therefore, seems to be the necessary effect of the peculiar organic structure with which nature has endowed them. Vegetable food contains a much less quantity of nutritious substance than animal. It must require, therefore, a much larger quantity of it to nourish and sustain the body, and it requires a longer time for it to digest. Those animals, therefore, that live entirely upon vegetables, have large and capacious stomachs, and their dispositions are characterized by mildness, complacency and innocence. Those animals that live upon flesh and vegetables combined, have not the small stomach of the carnivorous tribe, or the capacious ones of the herbivorous. In their dispositions they partake not of the cruelty of the one nor the mildness of the other.

All ruminating animals, or such as chew the cud, are furnished with no less than four stomachs. The food after it is masticated passes into the first stomach, where it remains till it is partially digested. — It is then thrown by the voluntary efforts of the animal into the mouth, where it undergoes a second chewing. The second time it is swallowed instead of passing into the first stomach it goes into the second, and so on to the third and fourth. The ruminating order of animals are distinguished for

their easy submission and their temerity. Horns are the only weapons of defence with which they are provided. We should naturally infer the character of their dispositions from the configuration of their bodies, and the nature of their food; for it must be obvious to all, that the diversities of taste and disposition in different animals, arise from a physical cause, depending upon the structure and formation of their bodies.

The *camel* and *dromedary*, in addition to the fore stomachs common to the ruminating tribe, are furnished with a bag or reservoir for the purpose of holding or conveying water. This reservoir is capable of containing a large quantity of water, and it can remain in it in as pure and limpid a state as when taken from the well: for no impurities of the body have access to it. When the camel is thirsty or has occasion to moisten his cud, by a simple contraction of a certain muscle, he is enabled to force the water into the first stomach, or even as far as the mouth. By this simple but curious formation, the camel is able to travel the sandy desert without drinking. Both their constitution and their structure are admirably adapted to the climate where they are produced, and to the uses which are made of them. The Arabians consider them as gifts sent from heaven, without whose assistance they could neither traffic or travel.

Birds have three stomachs. The food after it passes through the membranous tube that leads from the mouth, goes into the first stomach, where it is mixed with and acted upon by the fluid that is secreted by its coats. After it has been partly digested, it passes into the second stomach, and so on to the third, which is called the gizzard or true stomach, which consists of two very strong muscles lined with a thick and firm membrane. There are some birds (as for instance, rooks and pigeons) that have the power of throwing their food up from their first stomachs in a half digested state, for the purpose of feeding their young. Birds, like quadrupeds, are divided into herbivorous and carnivorous, and their dispositions and manners correspond to the formation of their bodies, and the food they require. Carnivorous birds have smaller stomachs than granivorous. Their wings are

usually longer that they may fly with more rapidity, and thereby be enabled to overtake their prey; — they have strong hooked bills and long sharp claws. The granivorous birds resemble very much the herbivorous quadrupeds, both in the capaciousness of their stomachs and in the mildness of their dispositions. It is among this class of birds that man, ever attentive to his interest, has made selections for the purpose of domestication. Carnivorous birds never, with but one exception, herd together in flocks, but they spend their time in some sequestered spot, or in the depths of the forest.

The influence of atmospheric air is absolutely necessary for the support of organic life. This is not confined to animal life: for vegetables cease to perform their functions when deprived of it, and the seed will not sprout unless it comes in contact with this elastic but all important fluid. Plants have no particular apparatus by which they respire, but they receive the air through every pore. Animals are furnished with a particular apparatus for the purpose of admitting air into the internal parts of the body. In man, and the most perfect animals, respiration, or the act of breathing, is carried on by means of organs called lungs, which are composed of an infinite number of air-cells and minute blood-vessels. Respiration consists of inspiration or the act of drawing in the air into the lungs, and expiration or the act of throwing it out. At each inspiration the little cells of the lungs are filled with air. These cells are surrounded by minute blood-vessels, and thus the blood which is thrown from the heart and the air which enters the lungs, are made to approximate each other.

Through the influence of the air which fills the cells, the blood in the minute vessels is so operated upon that it is deprived of its dark color, or is changed from a dark to a light red. This change takes place by the blood being deprived of its impurities, which, if allowed to circulate through the body, would not only unfit it for nourishment but life would soon be destroyed. The air which enters the lungs pure, returns from them loaded with impurities. Changing the impure into pure blood, or relieving it of a poisonous substance, are not all the

beneficial results of respiration. It is supposed that by the action of the air on the blood, the latter in some way receives an increased quantity of heat, or caloric, by which means the body maintains its fixed standard of temperature.

All animals furnished with lungs have the power of expressing their wants, their desires, their pleasures and their pains, by words or sounds peculiar to each species.

Birds, although they are furnished with lungs as well as quadrupeds, by a wise provision of nature, are enabled to fill almost every part of their bodies with air. They have air cells which communicate with their lungs situated in almost all parts of their bodies. They are situated not only in the soft parts but their bones are furnished with them. Mr Hunter tied up the natural air tube (*the Trachia*) of a hen, and made an opening into one of the bones furnished with a cell and the function of respiration was carried on by means of it. Mr Hunter often having made this and various other experiments to prove that air cells did exist, thought that this was a provision which nature had made, that birds being made comparatively light by being filled with air, and this after it had been dilated by the natural heat of the body, would perform with much more ease their aerial journeys. He afterwards however found that the ostrich which does not fly, was abundantly furnished with them, while the bat which does, had no such peculiarity of structure.

Insects breathe through small pores situated on the sides of their bodies or on their backs. Amphibious animals, or such as can live in two elements, have lungs which extend the whole length of their bodies.

Animals that reside in the water, require air as well as those that live on the land. The cetaceous tribe, such as the whale, are furnished with lungs like quadrupeds, but most fish are provided with gills, which answer the purpose of lungs. The water is made to pass over a small membrane, and the air which it contains or the oxygen of the water comes nearly in contact with the blood, and thus the important change is effected. The surface that is exposed to the action of the air in fish, and the blood necessary to supply the wants of the body are much less

than in birds or quadrupeds, for being situated in a fluid whose specific gravity is nearly equal to that of their bodies, it must require much less muscular exertion to move in that fluid than in the air or upon the surface of the earth.

Experiments have proved that full grown persons respire twentyfour thousand cubic inches of air per hour, or five hundred and ninety-six thousand per day. We will suppose that each time the heart contracts it throws one half ounce of blood to the lungs, which, by the way, is a small calculation: now we know that the heart contracts on an average about seventy times in a minute; thus thirty-five ounces of blood must be sent from the heart to the lungs per minute, making more than 120 pounds per hour, or 2880 pounds per day. Therefore the air cells, which are extremely delicate, in the course of twentyfour hours sustain the weight of about thirtynine hogsheads of air, and the minute blood vessels 2880 pounds of blood in the same length of time.

This estimate will give you some idea of the wonderful power which these tender organs possess, and of their importance in the animal economy. In man there is a strong and intimate connexion between the heart and lungs. If we cease to respire the heart ceases to act, or if the blood does not undergo its proper change in the lungs, that is, if it is not changed from a dark to a light red, or more properly, if it is not decarbonized, all the organs of the body as it were, immediately take cognizance of it, the heart ceases to act and the man dies. The question may be asked, how the blood coming in contact, or nearly so, with the air, can be so powerfully operated upon as that this change shall take place.

We know that this change does take place, and we know also that we cannot exist unless it does; but how this is effected, what is the power or mode by which it is done, we know not. We can only say that it is a vital process performed by a vital power. It surely has been supposed that the oxygen of the atmosphere and the carbon in the dark or venous blood, when coming in contact, or nearly so, united, and thus formed carbonic acid gas, which was expelled from the lungs at each expiration.

It is the carbon which makes the venous blood, or that which circulates in the veins dark, and when it is deprived of it, it becomes light red or arterial blood.

We have observed that only some of the higher classes of animals and men were furnished with proper lungs, but we have endeavored to show at the same time, that air was as absolutely necessary for the support of one organized being as another, as necessary for plants as animals, although the organs through which they receive it may materially differ.

We have thus described two functions that belong to all organized living beings, viz. that of assimilation or digestion and respiration. We now come to a third, which is called the *circulatory* function, which consists in the circulation of the fluids through the body. The circulatory function is carried on by means of vessels arranged in proper order. We have in part been obliged to anticipate this subject in order to convey a general idea of the importance of atmospheric air.

The circulatory function in man includes those vessels that convey the blood, which consist of a heart, arteries and veins. The heart is the central organ from which the blood is thrown and to which it returns. In man it has four cavities, two of which are called ventricles, and two auricles. The two auricles occupy the base or the superior and posterior portion, and the ventricles the inferior. On each side the auricle corresponds with its corresponding ventricle. In the right cavities are contained the dark or venous blood which is to be sent to the lungs, there to be submitted to the action of the air, and in the left the light or arterial blood which has undergone this action and which is to be sent to all parts of the body. The former receive therefore the blood from all parts of the body, and by contracting propel it to the lungs; the latter receive it from the lungs and send it to all parts of the body. Those vessels that convey the blood from the heart are called arteries, and those that return it to the heart are called veins.

In fish the heart has only two cavities, one auricle and one ventricle. The blood is received from all parts of the body into the auricle, this throws it into the ven-

tricle, from which proceeds a vessel that conveys it to the gills. In the gills the blood undergoes the same changes as in the lungs of men. After the change in the blood is effected, instead of returning to the heart it is taken up by small vessels and conveyed directly to all parts of the body. Insects have no real heart, but they are supplied with a small, simple, alternately contracting vessel, which answers the purpose of a heart. Plants have a circulatory system which consists of vessels, by means of which the nutriment is conveyed from the earth to the leaves, and from the leaves after it is assimilated to all the organs of which they are composed. This system in plants is as simple as it would be in man, if the food which enters the mouth passed into the stomach, and there after it had undergone the process of assimilation, it was taken up by small vessels and distributed to all parts of the body without being compelled to pass through a heart or lungs.

The opinion of the circulation of the blood through the body was loosely started by some of the early writers; but to obtain sufficient proof to support the doctrine was so difficult that it was abandoned almost as soon as conceived. Serveto, who lived in the 16th century, imperfectly taught it by pointing out the smaller circulation, or that through the lungs; but the illustrious *Harvey*, in the 17th century, established it by the most satisfactory experiments. He, like all great discoverers, had to combat the prejudices of mankind, but he had the happiness before his death to know that his doctrine was almost universally acknowledged. We rely at the present day upon the same proofs that Harvey did for the support of this doctrine. The proofs are deduced from the disposition of the heart and blood vessels, and from the following experiments. 'If we open an artery or a vessel that carries the blood from the heart, the blood which comes from the puncture flows in a direction from the heart, but if we open a vein or a vessel that conveys the blood to the heart the blood flows in an opposite direction. If we examine with a microscope the almost transparent vessels of frogs or other cold blooded animals, we see the blood flowing from the heart into the arteries—from these into the veins, and from the veins back again to the heart—thus completing its circular career.'

We have thus considered the three functions that belong to all organized beings, to plants as well as animals. We will now consider some of those which are only possessed by animals. We have before observed that animals were distinguished from plants by their power of locomotion or the power of moving from place to place in search of food or pleasure.

All objects with which we are acquainted are subject to the laws of motion, but so far as it regards motion they are divided into two classes; one class includes all those objects that are endowed with a self-moving power by means of a particular apparatus which compose a part of themselves. The other class includes all matter which has not the power within itself of moving itself, but which requires some external force to put it in motion, and when once in motion requires some external resistance to stop it. The first class is composed of animated organized beings, and the second of all unorganized substances. The force with which unorganized matter resists any change is proportioned to the quantity which a body contains. It is perfectly indifferent to rest or motion, and this indifference is the natural consequence of the most absolute inactivity.

The power of beginning motion without the aid of external influence belongs only to active, intelligent, organized beings. Animals having the power to move wherever their wants dictate or their desires prompt, must be endowed with a particular apparatus by which this power is effected.

This apparatus is called muscular. There are a great number of muscles in our bodies, and each muscle is composed of long parallel fibres, usually of a red color, soft, irritable and contractile. The muscular substance is what is usually called red-flesh. All muscles are capable of contracting, and it is by means of this power that all the motions of the body are effected. It is by means of these that we walk, move our hands, chew our food, and even breathe. The heart is composed of muscular fibres, and it is by their powerful contraction that the blood is thrown to the lungs and to all parts of the body. If we raise one hand to the head and place the

other upon the middle of the arm between the shoulder and elbow, we shall feel a muscle contract and form a hard cord. This muscle is attached to the shoulder bone at one end, and at the other, to one of the bones of the fore arm, and thus when it contracts or shortens, the necessary effect is to bend the arm at the elbow and bring the hand to the head.

In man and the highest order of animals there are two classes of muscles, those which contract under the influence of the will and those which contract independent of it. The former are called voluntary and the latter involuntary. The heart regularly contracts from the first moments of our existence to the last, as well when we are asleep as awake. It is not in the least influenced by the will. The regular contractions of the stomach also are entirely and absolutely independent of volition. The process of respiration is usually performed by means of the involuntary muscles. We can for a few moments cease to respire if we will, and if the involuntary muscles or the nerves leading to them are involved in any disease which unfits them for the performance of their duty, respiration may be performed under the control of the will, but this is extremely laborious and cannot be continued for any great length of time. Thence it would seem that the organs of respiration were furnished with voluntary and involuntary muscles, and this fact has been proved by the most satisfactory experiments.

Locomotion is performed altogether by means of the voluntary muscles. We will to move and immediately these muscles are in action.

If the contraction of the heart and the muscles of respiration were under the entire control of the will, the constant and unremitted exertions of the mind would be required — there would be no time for rest or sleep; for if there was a suspension of consciousness there would of course be a suspension of circulation and respiration, and immediate death would be the consequence.

Animals are alone endowed with a proper muscular apparatus, but some plants have the power of motion in an eminent degree. Their fibres therefore must have the power of contraction, and they must be endowed with

some irritability. If the leaves of a *sensitive plant* are touched they immediately shrink, and with the branches to which they are attached bend towards the earth. The leaves of the moving plant, a native of the East Indies, are so excited by the rays of the sun that they are constantly in motion while exposed to them. The plant called *Dionea muscipula* or *Venus' fly trap*, affords another example of rapid vegetable motion. The leaves of this plant are armed with rows of small prickles, and are covered by small glands which secrete a sweetish liquid that is extremely pleasant to flies. When a fly comes in contact with a leaf the two lobes rise up, the prickles are fastened together, and the unwary animal is destroyed. The motion of animals is somewhat influenced by their specific gravity. A flea can leap some hundred times its length, and spiders and worms fall with impunity from immense heights. If large animals should leap or fall as far in proportion to their weight or gravity, they would be crushed to atoms.

We have said that the voluntary muscles were under the control and influence of the will. The question may now be asked from what organ does the will emanate, and what are the means of communication between that organ and the muscles? The brain which is contained within the bony cranium is allowed by all to be the seat where all the faculties of the mind in man and of instinct in animals reside. From the brain and spinal column (which is a mere continuation of the brain) proceed fortytwo pair of shining inelastic cords called nerves, which differ from each other in size, color, and consistence. These nerves send off innumerable branches which are distributed like a net work over every part of the body. They are the immediate organs of sensation as well as of muscular motion. If the nerves which go to the arm were cut off, the muscles below the incision would lose all power of motion, and the skin of sensation. If the nervous communication between the brain and the eye, or ear, or tongue, were cut off, we could no more see, or hear, or taste. When we receive an impression on the finger, this impression is conveyed to the brain by means of nerves, and the mind takes cognizance of it.

So when an object strikes the eye, or sound the ear, the impression is communicated to the brain, and we then see or hear. The will in like manner conveys its stimulus along the nerve to the voluntary muscles, and immediately they contract, and motion is produced. Three things are necessary either for the mind to be acted upon by external objects or in its turn to act upon them. As it regards the senses there must be, 1st, an external sensitive organ adapted to the property of the body to be ascertained. 2d. There must be a nervous cord to transmit this sensation to the central mass; and 3d, there must necessarily be a central organ to perceive. As it regards the action of the will upon the voluntary muscles, there is an organ to will, a nervous cord to communicate it to the muscle, and consequently a muscle to contract.

To complete therefore the nervous system, three distinct organs are found in man and the most perfect animals. For example, in the eye we have an optical instrument, situated before a nervous agent to collect the image of the object to be perceived and to picture this upon the retina, the brain being made sensible of the impression of this image by the agency of the optic nerve, which is a medium of communication between the sense and sensorium. An animal deprived of the external senses may be said to live within himself, as he is destitute of all communication with the world around him. To him color, sound, heat and cold give no pleasure, neither do they produce pain. The lower classes of animals, as for example the zoophytes and worms, generally possess but one rudimentary sense, viz. that of feeling, which is exercised by an imperfectly organized integument covering the body. The nervous system is, strictly speaking, the most striking peculiarity of animals, and constitutes more especially what is called the animal life and the life of relation, by means of which the animal extends his relations and lives not only within himself but in connexion with surrounding objects.

The human brain exceeds that of the most perfect animals in the number and perfect development of its parts, none being found in any animal which man has not, while several parts found in the brain of man are either

reduced in size or are entirely wanting in various animals. 'It is said that by taking away, diminishing, or changing proportions, you might form from the brain of man that of any other animal, while there is no animal of whose brain you could in like manner compose that of man. The brain in man approaches more nearly a spherical form than that in any animal, and the nerves are smaller in proportion to the brain. 'The brain diminishes and the nerves increase from man downwards.' Plants have no nervous system, and the lowest order of animals have but imperfectly developed nerves, while they are destitute of a brain.

Men and the most perfect animals, in fact all vertebral animals, such as are furnished with a spinal marrow, have five senses, viz. seeing, hearing, tasting, smelling and feeling; but we have before observed, that the only sense which pervades the whole animal creation, was that of feeling. M. Cuvier thinks that the sense of feeling is the sensorial power manifested in its most simple state, and that all the other senses are mere modifications of it. The sense of feeling in man is more strongly developed in the tongue, lips, and ends of the fingers than in any other part of the body. In cows and horses the tongue and nostrils appear to be the local organs of touch. In the mole and pig the snout appears to be the peculiar organ which performs the office of feeling. The local organ of feeling in many of the feathered tribe appears to be situated in the membrane that lines their mandibles.

In the opossum it exists in the end of the tail; in insects in their antennæ, and in worms in their tentacula. It is not determined whether the fish and amphibious animals are furnished with any local organ of the sense of feeling or not. We would here remark, that although every sensation may be comprehended under the term feeling, yet when we speak of it as a distinct sense, we would restrict it to the different sensations excited by different substances when applied to the integument which covers the body of men and animals, or more particularly to those organs which we have mentioned as being local, but which perform in an eminent degree the office of feeling. It is certain that in man, the

eyes, ears, tongue, lips, nose, and ends of the fingers are more abundantly supplied with nerves than any other part of the body. The immediate instruments of sensation are small *nervous papillæ*, which are soft pulpy terminations of the nerves. These papillæ cover the whole surface of the skin, but they may be seen more distinctly, for they are more fully developed on the tongue and ends of the fingers than any other organs which we can without difficulty examine with the naked eye. 'When examining or enjoying an object,' says *Smellie*, 'it is natural to inquire what are the changes produced in the nervous papillæ or organs of sensation. If an object possessed of agreeable feelings is perceived, the nervous papillæ instantly extend themselves, and from a state of flaccidity become comparatively rigid. This extension of the papillæ is not conjectural, but it is founded on anatomical examination, and may be felt by persons of acute and discerning sensation. When a man in the dark inclines to examine any substance in order to discover its figure or other qualities, he perceives a kind of rigidity at the tips of his fingers. If they are kept long in this state, the tension of the nervous papillæ will produce a kind of pain or anxiety which it is impossible to describe. If a small insect crawls on a man's hand when the papillæ are flaccid, its movements are not perceived; but if he sees the animal he immediately extends his papillæ, and feels all its motions. If a body be present, which in the common state of the nerves has scarcely any sensible odor, by extending the papillæ of the nostrils an agreeable, disagreeable or indifferent smell will be perceived. When two persons are whispering, and we wish to know what is said, we stretch the papillæ of the ear, and an impression is made on them. If the sound is too low to make an impression on the papillæ in their natural flaccid state, we are apt to overstretch them, and this produces a painful or disagreeable feeling. When we examine a minute object with the naked eye, a pain is propagated over every part of that organ. Several causes may concur in producing this pain, such as the dilating of the pupil or the adjusting of the crystalline lens; but the chief cause must be ascribed to the preternatural exten-

sion of the papillæ of the retina, the substance of which is a mere congeries of nervous terminations.' This circumstance confirms a former remark, that the immediate organs of sensation were more copiously supplied with nervous papillæ than those parts whose uses require no such exquisite sensibility; for a distinction in this respect is observable even among the sensitive organs themselves. The eye is furnished with more of these papillæ than any other organ, and this would seem a necessary provision when we consider the minuteness of the particles of light, the impressions of which that organ is fitted to receive.

'The pleasure or pain produced by the sense of touch, depends chiefly on the friction or number of impulses made upon the papillæ. Embrace any agreeable body with your hand, and allow it to remain perfectly at rest, and you will find the pleasure not half so exquisite as when the hand is moved backwards and forwards upon its surface. Apply the hand to a piece of velvet, and it is merely agreeable; but rest it repeatedly on the surface of the cloth, and the pleasant feeling will be augmented in proportion to the number of impulses on the papillæ. When a man is hungry, the sight or idea of palatable food raises the whole papillæ of his tongue and stomach. From this circumstance he is highly regaled by eating.' But if he eats the same species of food when his stomach is in a less fit state to receive it, the papillæ remain in a flaccid state, and the pleasure is lessened. By the sense of touch we are enabled to ascertain some of the most important properties of bodies, such as their softness or hardness, their rough or smooth state, their figure and their size; and it is less deceptive than either of the other senses, because in order to effect it bodies must come in contact with the organ or organs which perform it, whereas in the other senses some intermediate substance may serve to modify or alter the impressions, and thus mislead the judgment.

The senses of tasting and smelling are more nearly assimilated to the sense of feeling than those of seeing and hearing; for bodies must come in contact with the papillæ of the tongue or palate in order that we may

taste; with the olfactory nerves that we may smell, as well as in contact with the papillæ of the skin that we may feel, although to the former, and especially to the olfactories, a substance must be presented in a more attenuated form.

The sense of taste in the most perfect animals resides in the papillæ of the tongue, and palate. In insects it is supposed by some naturalists to reside in the antennæ in combination with the sense of touch. The duck tribe are capable of distinguishing the quality of their food in the mud, and it is difficult to tell whether the sense of taste resides in their mandibles together with that of smell and touch or not.

The organ of taste is so situated that it may be truly called the guardian of the stomach; for before food can enter that organ, its noxious or its salutary qualities are subjected to its particular scrutiny. The tongue must be moistened with saliva, and the food must partially be dissolved before the sense of taste can be excited, or the qualities of the food ascertained. If the tongue is perfectly dry, as it sometimes is rendered by disease, the sense of taste is vitiated, if not annihilated. This sense, like all the other senses in man, is often perverted, so that substances which were originally unpleasant, become highly delicious and agreeable. This is never the case with animals.— Their taste remains as pure as when originally formed.— They are not subjected to the caprices of fashion or fastidious flights of ever varying fancy. Animals have no compounds, but they eat their food in its simple state. They know of no medley messes, in which a poison may be swallowed without perceiving it.

In such animals as have nostrils, the sense of smell resides in the nerves that are distributed on the membrane which lines them. The acuteness of this sense differs in different animals. The dog has it in a much more perfect state than man. It is generally found that this sense in its acuteness is in proportion to the extent of the membrane that is exposed. In dogs, and in most quadrupeds, it possesses a variety of folds, whereby a large surface is exposed. In birds it extends to the extreme points of the nostrils. In the elephant

this membrane extends the whole length of its proboscis.

In most fish the nostrils are double ; but in a few they are quadruple. Their sense of smell must therefore be very acute, and afford them a powerful inlet of pleasure. Some kinds of fish are extremely fond of aromatic substances, and are thereby easily led into the snares of the angler, when he is disposed to take advantage of their weakness.

The blowing holes of the cetaceous tribes are supposed to be their organs of smell ; but this is by no means certain. This sense is supposed to exist in most amphibials and worms ; but where the organ is located, if there is any distinct organ, is not known.

Where the organ of sense resides in insects, is not certainly determined. That they have the power of distinguishing the odorous properties of substances in an eminent degree, is a well established fact ; but whether it is developed in the stigmata or feelers, or some other organ, has not yet been ascertained.

The olfactory nerves are immediately exposed, but they are in a measure protected from the action of the air, which is constantly passing over them during the process of respiration, and from acrid substances, by the mucus which covers them, and which is secreted by glands embedded in the membrane.

Almost all bodies in nature, whether animate or inanimate, send forth some odor. This odor circulates in the atmosphere, and comes in contact with the olfactory nerves of different animals, and produces in them different sensations. To one animal the odor of a plant may be highly agreeable, but to another extremely unpleasant.

It is fortunate for animals and for mankind, that the same materials produce different impressions — that there is a variety of tastes — that no two individuals are exactly alike either in form, feeling, character, or expression ; for this variety is the source of everything that is beautiful or interesting in the physical as well as the moral world.

The organs of tasting and smelling in all animals are so situated as to render mutual assistance to each other,

They are always contiguous. The sense of smelling may become perverted as well as that of tasting. Odors that were originally unpleasant to us, may by habitual use become not only agreeable but apparently necessary. The nervous papillæ may be so changed that the same material presented at different times may produce entirely different impressions, or they may lose their natural irritability so much as not to be easily excited.

The senses of hearing and seeing are more refined than those of feeling, tasting, or smelling; and the organs in which the former reside, or through which the impressions are conveyed, are far more complicated in their structure than those of the latter.

The organ of hearing in men, and the most perfect animals, is the ear. In these there are two distinct openings into the ear, a larger or external, (which is surrounded by a lobe so constructed as in the best manner possible to collect the undulation of the air produced by sonorous bodies, and convey the same to the nerves situated in the internal ear, which convey the impression of sound to the brain,) and an internal opening which passes from the mouth into the ear, and which is called the Eustachion tube. When a person is desirous of hearing, and the sound is imperfect, the mouth is involuntarily opened, and the sound is thus conveyed through this tube. Frogs, and most amphibious animals have no external ear, but they hear by means of the internal passage or that from the mouth. Among serpents the common harmless snake or blind worm is the only one that has an aperture which leads to the internal ear, that can be discovered. All others have the internal organs developed in an imperfect manner; and it is therefore probable, at least, that there is some effective entrance to them. The whole cetaceous tribe hear through their nostrils or blow-holes.

Among fishes, the shark and a few others have the rudiments of an external ear; but most of the tribe hear through the external opening alone. Insects have the sense of hearing; but it is questionable by what organ it is performed. — Some have supposed that the antennæ performed this office in combination with several other

of the senses; but the question would then arise, how do those animals hear that have no antennæ? Spiders hear, or at least we have conclusive evidence of this fact, and yet they have no antennæ.

‘Hearing enables us to perceive all the agreeable sensations conveyed to our minds by the melody and harmony of sounds. This to men at least is a great source of pleasure as well as of innocent amusement. Some men are, however, almost destitute of the faculty of distinguishing musical sounds, and of perceiving those delightful and diversified feelings excited by the various combinations of musical tones. An ear for music, however, though not to be organized by study when the faculty is wanting, may be highly improved by habit and culture. Buffon, after examining a number of persons who had no ear for music, says that every one of them heard worse in one ear than in the other, and ascribes their inability of distinguishing expressions to that defect. But a musical ear seems to have no dependence on acuteness or bluntness of hearing whether in one or in both. There are examples of people who may be said to be half deaf, and yet are both fond of music, and skilful practitioners.’ For a full and scientific description of the organs of vision, see No. V. on the mechanism of the eye, by Dr Smith.

We have thus taken a general survey of the properties and functions which belong to all organized beings.

It may serve to enlighten those who have but little time and less means to attend to scientific pursuits, or stimulate those who have to a closer examination of the subject. If either of these purposes are effected, the writer will feel himself happy, and will rejoice at the opportunity which has thus been given for the effort of his feeble talents.

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SCIENTIFIC TRACTS.

NUMBER XVIII.

WHALE FISHERY.

INTRODUCTORY REMARKS.

THERE are many circumstances which unite to give interest to everything relating to the huge animal, the method of whose capture is to be the subject of the following Tract. We shall first briefly allude to some of these circumstances, and then proceed to describe in detail the animating scenes which are presented in these terrific conflicts between human ingenuity on the one hand and brute, but monstrous power, on the other.

1. *The Structure of the Whale.* Most of the inhabitants of the sea breathe no air — their blood is cold — and their young is produced by spawn, which is always abandoned by the parent to the winds and waves. The family of *cetaceous* animals, however, have *warm* blood — they breathe the air — they produce living offspring, which they cherish and protect while young. These things occasion a great difference of structure. They breathe. Consequently, they are generally near the surface of the water, and often come to it to take breath, giving a sort of puff, from which the sailors have given them all the name of *blowers*. They are warm blooded. They therefore have a thick coating of fat for clothing. It is for this clothing that they are chiefly valuable to man.

2. *The Commercial Importance of the Whale Fishery.* A very large amount of capital, both in the shape of money and of men, is employed in this trade, from this country. This amount, too, is increasing. And from present appearances it is probable that it will increase

still farther, both in this country and Europe. The parts of the animal are converted to a great variety of purposes. The flesh, though rejected by Europeans, is the principal food of many savage tribes on the coast of the northern seas. They construct, also, windows of some thin semi-transparent membranes found in the animal; — they make weapons of war from the bones, and cords from the sinews. The chief articles of value, however, are the oil, and the whalebone, as it is called. This latter substance is not properly bone. It is found in laminæ in the mouth of the animal, in the place of teeth.

3. *The very interesting Nature of the Fishery.* The excitement, the danger, the magnitude of the object of the chase, conspire to throw an intensity of interest about this subject, which can be found in very few of the modes in which human ingenuity and enterprise are exerted.

For the above reasons we shall present, chiefly from the writings of Capt. Scoresby, the universal authority on this subject, a full description of the whale fishery. Capt. Scoresby was a whaler himself — and he united to the most favorable opportunities of observation, a mind admirably adapted to seize on the striking and prominent features of a scene, and to describe them with vividness and force.

INSTRUMENTS USED IN THE WHALE FISHERY.

Whale Ships. The ships are fitted out for this purpose with apparatus for taking the whale, cutting up the animal, and extracting the oil, and also with a large supply of casks to contain it. They sail so as to be upon the fishing stations in the northern latitudes, in the spring of the year.

Whale Boats. A whale boat is constructed in such a manner that it differs in many important respects from other boats. It is lighter, — more easily turned, — it moves more swiftly. They are twenty or twentyfive feet long, and between five and six feet wide.

Weapons. The chief weapon is the harpoon, of which the adjoining cut is a representation. The part marked *m* is call-

ed the mouth. It consists simply of a doubly barbed point. The slender part, marked *s*, connecting this with the handle, is of very ductile iron, so as to bend and twist in any direction by the efforts of the whale, without breaking. A very flexible but strong rope is attached to the harpoon. It is of great length and one end is retained in the boat. In addition to the harpoon, there is a *lance*, which is a spear of iron, with a very sharp steel point. It is used for finally despatching the whale, after he is almost exhausted in the contest.

PROCEEDINGS ON FISHING STATIONS.

Discovery of the Whale. On fishing stations, when the weather is such as to render the fishing practicable, the boats are always ready for instant service. Suspended from davits or cranes by the side of the ship, furnished with the requisite implements, two boats at least, the crews of which are always in readiness, can in a general way, be manned and lowered into the water, within the space of one minute of time.

Wherever there is a probability of seeing whales, when the weather and situation are such as to present a possibility of capturing them, the *crowsnest*, as it is called, i. e. a station at the mast head, is generally occupied by the master or some of the officers, who, commanding from thence an extensive prospect of the surrounding sea, keeps with the assistance of a telescope, an anxious watch for the appearance of a whale. The moment that a fish is seen, he gives notice to the 'watch upon deck,' part of whom leap into a boat, are lowered down, and push off towards the place. If the fish be large, a second boat is immediately despatched to the support of the other. When the whale again appears — for if he has gone down he must soon come up again to breathe — two boats row towards it with the utmost speed; and though they may be disappointed in their attempts, they generally continue their pursuit until the fish either takes the alarm, and escapes them, or they are recalled by signal to the ship. When two or more fish appear at the same time in different situations, the number of boats sent in pursuit is in-

creased, and sometimes all the boats are sent out. During fine weather, in situations where whales are seen, or where they have recently been seen, or where there is a great probability of any making their appearance, a boat is generally kept in readiness, manned and afloat. If the ship sails with considerable velocity, this boat is towed by a rope astern; but when the ship is pretty still, whether moored to ice, laid to, or sailing in light winds, the 'bran boat,' as it is called, often pushes off to a little distance from the ship. A boat on watch commonly lies still in some eligible situation with all its oars elevated out of the water, but in readiness, in the hands of the rowers, for immediate use.

The harpooner and boat steerer keep a careful watch on all sides, while each of the rowers looks out in the direction of his oar. Thus the whole horizon is under close observation. In fishing near fields of ice, the boats approach the ice with their sterns, and are each of them fastened to it by means of a boat hook, or an iron spike with a cord attached, either of which is held by the boat steerer, and is slipped or withdrawn the moment a whale appears. There are several rules observed in approaching a whale, as precautions, to prevent, as far as possible, the animal from taking the alarm.

As the whale is dull of hearing, but quick of sight, the boat steerer always endeavors to get behind it; and, in accomplishing this, he is sometimes justified in taking a circuitous route. In calm weather the greatest caution is necessary, before a whale can be reached; smooth, careful rowing, is always requisite, and sometimes sculling is practised.

A whale seldom abides longer on the water than two minutes, and it generally remains from five, to ten or fifteen minutes under water. During this interval, it sometimes moves through a space of half a mile or more, and the fisher has very rarely any certain intimation of the place in which it will reappear. Consequently, the difficulty and address requisite to approach sufficiently near, during its short stay on the surface, to harpoon it, is very great.

It is, therefore, a primary consideration with the har-

pooner, always to place his boat as near as possible to the spot, in which he expects the fish to rise, and he conceives himself successful in the attempt when the fish 'comes up *within a start*,' that is, within the distance of about two hundred yards.

In all cases when a whale that is pursued, has but once been seen, the fisher is considerably indebted to what is called chance for a favorable position. But when the whale has been twice seen, and its change of place, if any, noticed, the harpooner makes the best use of the intimation derived from his observation on its apparent motion, and places his boat accordingly. Thus he anticipates the fish in its progress, so that when it rises to the surface, there is probability of its being within the favorable precincts of a start. A whale moving forward at a small distance beneath the surface of the sea, leaves a sure indication of its situation, in what is called an 'eddy,' having somewhat the resemblance of the 'wake' or track of a ship; and in fine calm weather, its change of position is sometimes pointed out by the birds, many of which closely follow it when at the surface, and hover over it when below, whose keener vision can discover it, when it is totally concealed from human eyes. By these indications many whales have been taken.

THE ATTACK AND PURSUIT.

Whenever a whale lies on the surface of the water, unconscious of the approach of its enemies, the hardy fisher rows directly upon it, and an instant before the boat touches it, buries his harpoon in its back. But if, while the boat is yet at a little distance, the whale should indicate his intention of diving, by lifting his head above the common level, and then plunging it under water, and raising its body until it appear like the large segment of a sphere, — the harpoon is thrown from the hand, or fired from a gun, the former of which, when skilfully practised, is efficient at the distance of eight or ten yards, and the latter at the distance of thirty yards or upwards. The wounded whale, in the surprise and agony of the moment, makes a convulsive effort to escape. Then is the moment of danger. The boat is subjected to the most violent blows from its head

or its fins, but particularly from its ponderous tail, which sometimes sweeps the air with such tremendous fury, that both boat and men are exposed to one common destruction.

The head of the whale is avoided, because it cannot be penetrated with the harpoon; but any part of the body, between the head and tail, will admit of the full length of the instrument, without danger of obstruction. The harpoon, therefore, is always struck into the back, and generally well forward towards the fins, thus affording the chance, when it happens to drag and plough along the back, of retaining its hold during a longer time, than when struck in closer to the tail.

The moment that the wounded whale disappears, or leaves the boat, a jack or flag, elevated on a staff, is displayed, on sight of which, those on watch in the ship, give the alarm, by stamping on the deck, accompanied by a simultaneous and continued shout of 'a fall.*' At the sound of this, the sleeping crew are roused, jump from their beds, rush upon deck, with their clothes tied by a string in their hands, and crowd into the boats, with a temperature of zero. Should a fall occur, the crew would appear upon deck, shielded only by their drawers, stockings, and shirts, or other habiliments in which they sleep. They generally contrive to dress themselves, in part, at least, as the boats are lowered down; but sometimes they push off in the state in which they rise from their beds, row away towards the 'fast boat,' that is, the boat attached by its harpoon and line, to the whale, and have no opportunity to clothe themselves for a length of time afterwards. The alarm of 'a fall' has a singular effect on the feelings of a sleeping person, unaccustomed to the whale fishing business. It has often been mistaken for a cry of distress. A landsman in a Hull ship, seeing the crew, on the occasion of a fall, rush upon deck, with their clothes in their hands, when there was no appearance of danger, thought the men were all mad; but

* The word 'fall,' as well as many others used in the fishery, is derived from the Dutch language. In the original it is written *val*, implying jump, drop, fall, and is considered expressive of the conduct of the sailors, when manning the boats, on an occasion requiring extreme despatch.

with another individual, the effect was totally different. Alarmed with the extraordinary noise, and still more so, when he reached the deck, with the appearance of all the crew seated in the boats in their shirts, he imagined the ship was sinking. He therefore endeavored to get into a boat himself, but every one of them being fully manned, he was always repulsed. After several fruitless endeavors to gain a place among his comrades, he cried out, with feelings of evident distress, 'What shall I do?—will none of you take me in?'

The first effort of a 'fast fish,' or whale that has been struck, is to escape from the boat, by sinking under water. After this, it pursues its course directly downward, or reappears at a little distance, and swims with great celerity, near the surface of the water, towards any neighboring ice, among which it may attain an imaginary shelter; or it returns instantly to the surface, and gives evidence of its agony, by the most convulsive throes, in which its fins and tail are alternately displayed in the air, and dashed into the water with tremendous violence. The former behaviour, however, that is, to dive towards the bottom of the sea, is so frequent, in comparison of any other, that it may be considered as the general conduct of a fast fish.

A whale struck near the edge of any large sheet of ice, and passing underneath it, will sometimes run the whole of the lines out of the boat, in the space of eight or ten minutes of time. This being the case, when the 'fast boat' is at a distance, both from the ship and from any other boat, it frequently happens that the lines are all withdrawn before assistance arrives, and, with the fish, entirely lost. In some cases, however, they are recovered. To retard, therefore, as much as possible, the flight of the whale, it is usual for the harpooner, who strikes it, to cast one, two, or more turns of line round a kind of post, called a ballard, which is fixed within ten or twelve inches of the stern of the boat, for the purpose. Such is the friction of the line, when running round the ballard, that it frequently envelopes the harpooner in smoke; and if the wood were not repeatedly wetted, would probably set fire to the boat. During the capture

of one whale, a groove is sometimes cut in the ballard, near an inch in depth; and, were it not for a plate of brass, iron, or a block of *lignum vitæ*, which covers the top of the stem where the line passes over, it is apprehended that the action of the line on the material of the boat, would cut it down to the water's edge, in the course of one season of successful fishing. The approaching distress of a boat, for want of line, is indicated by the elevation of an oar, in the way of a mast, to which is added a second, a third, or even a fourth, in proportion to the nature of the exigence. The utmost care and attention are requisite, on the part of every person in the boat, when the lines are running out; fatal consequences having been sometimes produced by the most trifling neglect. When the line happens 'to run foul,' and cannot be cleared on the instant, it sometimes draws the boat under water; on which, if no auxiliary boat, or convenient piece of ice be at hand, the crew are plunged into the sea, and are obliged to trust to the buoyancy of their oars, or to their skill in swimming, for supporting themselves on the surface. To provide against such an accident, as well as to be ready to furnish an additional supply of lines, it is usual, when boats are sent in pursuit, for two to go out in company, and when a whale has been struck, for the first assisting boat which approaches, to join the fast boat, and to stay by it until the fish reappears. The other boats, likewise, make towards the one carrying a flag, and surround it at various distances, awaiting the appearance of the wounded whale.

On my first voyage* to the whale-fishery, such an accident, as above alluded to, occurred. A thousand fathoms of line were already out, and the fast boat was forcibly pressed against the side of a piece of ice. The harpooner, in his anxiety to retard the flight of the whale, applied too many turns of the line round the ballard, which getting entangled, drew the boat beneath the ice. Another boat, providentially, was at hand, into which the crew, including myself, who happened to be present, had just time to escape.

* Capt. Scoresby.

The whale, with near two miles' length of line, was, in consequence of the accident, lost, but the boat was recovered. On a subsequent occasion, I underwent a similar misadventure, but with a happier result; we escaped with a little wetting into an accompanying boat, and the whale was afterwards captured, and the boat with its lines recovered.

When fish have been struck by myself, I have on different occasions estimated their rate of descent. For the first 300 fathoms, the average velocity was usually after the rate of eight to ten miles per hour. In one instance, the third line of 120 fathoms was run out in sixty-one seconds; that is at the rate of eight and one sixth English miles, or seven and one eighth nautical miles per hour. By the motions of the fast boat, the simultaneous movements of the whale are estimated. The auxiliary boats, accordingly, take their stations about the situation where the whale, from these motions, may reasonably be expected to appear.

The average stay under water, of a wounded whale, which steadily descends after being struck, according to the most usual conduct of the animal, is about thirty minutes. The longest I ever observed was fiftysix minutes, but in shallow water, I have been informed, it has sometimes been known to remain an hour and a half at the bottom after being struck, and yet has returned to the surface alive. The greater the velocity, the more considerable the distance to which it descends, and the longer the time it remains under water, so much greater in proportion is the extent of its exhaustion and the consequent facility of accomplishing its capture. Immediately on its reappearing, the assisting boats make for the place with their utmost speed, and as they reach it, each harpooner plunges his harpoon into its back, to the amount of three, four, or more, according to the size of the whale, and the nature of the situation. Most frequently, however, it descends for a few minutes after receiving the second harpoon, and obliges the other boats to await its return to the surface, before any further attack can be made. It is afterwards actively plied with lances, which are thrust into its body, aiming at its vitals.

At length, when exhausted by numerous wounds and the loss of blood, which flows from the huge animal in copious streams, it indicates the approach of its dissolution, by discharging from its 'blowholes,' a mixture of blood along with the air and mucus which it usually expires, and finally jets of blood alone. The sea, to a great extent around, is dyed with its blood, and the ice, boats, and men, are sometimes drenched with the same. Its track is likewise marked by a broad pellicle of oil, which exudes from its wounds, and appears on the surface of the sea.

Its final capture is sometimes preceded by a convulsive struggle, in which, its tail, reared, whirled, and violently jerked in the air, resounds to the distance of miles. In dying, it turns on its back or on its side, which joyful circumstance is announced by the capturers with the striking of their flags, accompanied by three lively huzzas!

The remarkable exhaustion observed in the first appearance of a wounded whale at the surface, after a descent of 700 or 800 fathoms perpendicular, does not depend on the nature of the wound it has received, for a hundred superficial wounds received from harpoons, could not have the effects of a single lance penetrating the vitals, but is the effect of the almost incredible pressure to which the animal must have been exposed. The surface of the body of a large whale, may be considered as comprising an area of 1540 square feet. This, under the common 'weight of the atmosphere only, must sustain a pressure of 3,104,640 pounds, or 1386 tons. But at the depth of 800 fathoms, where there is a column of water equal in weight to about 154 atmospheres, the pressure on the animal must be equal to 211,200 tons. This is a degree of pressure of which we can have but an imperfect conception. It may assist our comprehension, however, to be informed, that it exceeds in weight sixty of the largest ships of the British navy when manned, provisioned, and fitted for a six months' cruise.

Every boat fast to a living whale carries a flag, and the ship to which such boats belong, also wears a flag, until the whale is either killed or makes its escape.

These signals serve to indicate to surrounding ships the exclusive title of the 'fast ship,' to the entangled whale, and to prevent their interference, excepting in the way of assistance, in the capture. A very natural inquiry connected with this subject, is, what is the length of time requisite for capturing a whale? This is a question which can only be answered indirectly; for I have myself witnessed the capture of a large whale, which has been effected in twentyeight minutes; and have also been engaged with another fish which was lost, after it had been entangled about sixteen hours. Instances are well authenticated, in which whales have yielded their lives to the lances of active fishers, within the space of *fifteen minutes* from the time of being struck; and in cases when fish have been shot with a harpoon-gun, in a still shorter period; while other instances are equally familiar and certain, wherein a whale having gained the shelter of a pack or compact patch of ice, has sustained or avoided every attack upon it, during the space of forty or fifty hours. Some whales have been captured when very slightly entangled with a single harpoon, while others have disengaged themselves, though severely wounded with lances, by a single act of violent and convulsive distortion of the body, or tremendous shake of the tail, from four or more harpoons; in which act, some of the lines have been broken with apparent ease, and the harpoons to which other lines were attached, either broken or torn out of the body of the vigorous animal. Generally, the speedy capture of a whale depends on the activity of the harpooners, the favorableness of situation and weather, and, in no inconsiderable degree, on the peculiar conduct of the whale attacked. Under the most favorable circumstances, namely, when the fishermen are very active, the ice very open, or the sea free from ice and the weather fine,—the average length of time occupied in the capture of a whale, may be stated as not exceeding an hour. The general average, including all sizes of fish, and all circumstances of capture, may probably be two or three hours.

The method practised in the capture of whales, under favorable circumstances, is very uniform with all the fish-

ers of every nation. The only variation observable in the proceedings of the different fishers, consisting in the degree of activity and resolution displayed, in pursuance of the operations of harpooning and lancing the whale, and in the address manifested in improving by any accidental movement of the fish, which may lay it open to an effectual attack, — rather than in anything different or superior in the general method of conducting the fishery. It is true, that with some the harpoon-gun is much valued, and used with advantage, while with others, it is held in prejudiced aversion; yet, as this difference of opinion affects only the first attack and entanglement of the whale, the subsequent proceedings with all the fishers, may still be said to be founded on equal and unanimous principles. Hence, the mode described in the preceding pages, of conducting the fishery for whales under favorable circumstances, may be considered as the general plan pursued by the whalers of all nations. Neither is there any difference in the plan of attack, or mode of capture between fish of large size, and those of lesser growth; the proceedings are the same, but, of course, with the smaller whales less force is requisite; though it sometimes happens that the trouble attached to the killing of a very small whale, exceeds that connected with the capture of one of the largest individuals. The progress or flight of a large whale cannot be restrained; but that of an under size fish may generally be confined within the limits of 400 to 600 fathoms of line. A full grown fish generally occupies the whole, or nearly the whole of the boats belonging to one ship in its capture; but three, four, or sometimes more small fish, have been killed at the same time, by six or seven boats. It is not unusual for small whales to run downward until they exhaust themselves so completely, that they are not able to return to the surface, but are suffocated in the water. As it is requisite that a whale that has been drowned should be drawn up by the line, which is a tedious and troublesome operation, it is usual to guard against such an event by resisting its descent with a light strain on the line, and also by hauling upon the line, the moment its descent is stopped, with a view of inducing it to re-

turn to the surface, where it can be killed and secured without further trouble. Seldom more than two harpoons are struck into an under size whale.

The ease with which some whales are subdued, and the slightness of the entanglement by which they are taken, is truly surprising; but with others it is equally astonishing, that neither line nor harpoon, nor any number of each, is sufficiently strong to effect their capture. Many instances have occurred where whales have escaped, from four, five, or even more harpoons, while fish, equally large, have been killed through the medium of a single harpoon. Indeed, whales have been taken in consequence of the entanglement of a line, without any harpoon at all; though, when such a case has occurred, it has evidently been the result of accident. The following instances are in point.

A whale was struck from one of the boats of the ship *Nautilus* in Davis's Straits. It was killed, and as is usual after the capture, it was disentangled of the line connected with the first 'fast-boat,' by dividing it within eight or nine yards of the harpoon. The crew of the boat from which the fish was first struck, in the meantime were employed in heaving in the lines, by means of a crank fixed in the boat for the purpose, which they progressively effected for some time. On a sudden, however, to their great astonishment, the lines were pulled away from them, with the same force and violence, as by a whale when first struck.

They repeated their signal indicative of a whale being struck; their shipmates flocked towards them, and while every one expressed a similar degree of astonishment with themselves, they all agreed that a fish was fast to the line. In a few minutes, they were agreeably confirmed in their opinion, and relieved from suspense, by the rising of a large whale close by them, exhausted with fatigue, and having every appearance of a fast-fish. It permitted itself to be struck by several harpoons at once, and was speedily killed. On examining it after death, to discover the cause of such an interesting accident, they found the line, belonging to the above mentioned boat, in its mouth, where it was still firmly

fixed by the compression of its lips. The occasion of this happy and puzzling accident, was therefore solved; — the end of the line, after being cut from the whale first killed, was in the act of sinking in the water; the fish in question, engaged in feeding, was advancing with its mouth wide open, and accidentally caught the line between its extended jaws; — a sensation so utterly unusual as that produced by the line, had induced it to shut its mouth and grasp the line, which was the cause of its alarm, so firmly between its lips, as to produce the effect just stated. This circumstance took place many years ago, but a similar one occurred in the year 1814.

A harpooner, belonging to the Prince of Brazil, of Hull, had struck a small fish. It descended, and remained for some time quiet, and at length appeared to be drowned. The strain on the line being then considerable, it was taken to the ship, with a view of heaving the fish up. The force requisite for performing this operation, was extremely various; sometimes the line came in with ease, at others, a quantity was withdrawn with great force and rapidity. As such, it appeared evident that the fish was yet alive. The heaving, however, was persisted in, and after the greater part of the lines had been drawn on board, a dead fish appeared at the surface, secured by several turns of the line round its body. It was disentangled with difficulty, and was confidently believed to be the whale they had struck. But when the line was cleared from the fish it proved to be merely the 'bight,' for the end still hung perpendicularly downward. What was then their surprise to find that it was still pulled away with considerable force. The capstan was again resorted to, and shortly afterwards, they hove up, also dead, the fish originally struck with the harpoon still fast. Hence it appeared, that the fish first drawn up, had got accidentally entangled with the line, and in its struggles to escape, had still further involved itself, by winding the line repeatedly round its body. The first fish entangled, as was suspected, had long been dead; and it was this lucky interloper, that occasioned the jerks and other singular effects observed on the line.

EXTRAORDINARY CASES.

Hitherto I have only attempted to describe the method adopted for the capture of whales under favorable circumstances, such as occur in open water, or amongst open ice in fine weather. As however this method is subject to various alterations, when the situation and circumstances are peculiar, I shall venture a few remarks on the subject.

1. *Pack Fishing.* The borders of close packs of drift ice, are frequently a favorite resort of large whales. To attack them in such a situation subjects the fisher to great risks in his lines and boats, as well as uncertainty in affecting their capture. When a considerable swell prevails on the borders of the ice, the whales on being struck, will sometimes recede from the pack, and become the prize of their assailers; but most generally flee to it for shelter, and frequently make their escape. To guard against the loss of lines as much as possible, it is pretty usual either to strike two harpoons from different boats at the same moment, or to bridle the lines of a second boat upon those of the boat from which the fish is struck. This operation consists in fixing other lines to those of the fast-boat at some distance from the harpoon, so that there is only one harpoon and one line immediately attached to the fish, but the double strength of a line from the place of their junction to the boats. Hence, should fish flee directly into the ice and proceed to an inaccessible distance, the two boats bearing an equal strain on each of their lines, can at pleasure draw the harpoon, or break the single part of the line immediately connected with it, and in either case, secure themselves against any considerable loss.

When a pack, by its compactness, prevents boats from penetrating, the men travel over the ice, leaping from piece to piece, in pursuit of the entangled whale. In this pursuit they carry lances with them and sometimes harpoons, with which, whenever they can approach the fish, they attack it, and if they succeed in killing it they drag it towards the exterior margin of the ice, by means of the line fastened to the harpoon with which it is origi-

nally struck. In such cases, it is generally an object of importance to sink it beneath the ice ; for effecting which purpose, each lobe of the tail is divided from the body, excepting a small portion of the edge, from which it hangs pendulous in the water. If it still floats, bags of sand, kedges or small cannon are suspended by a block on the bight of the line, wherewith the buoyancy of the dead whale is usually overcome. It then sinks, and is easily hauled out by the line into the open sea.

To particularize all the variety of pack fishing arising from winds and weather, size of the fish, state and peculiarities of the ice, &c, would require more space than the interest of the subject, to general readers, would justify. I shall, therefore, only remark, that pack fishing is, on the whole, the most troublesome and dangerous of all others ; — that instances have occurred of fish having been entangled during forty or fifty hours, and have escaped after all ; — and that other instances are remembered, of ships having lost the greater part of their stock of lines, several of their boats, and sometimes, though happily, less commonly, some individuals of their crew.

2. *Field Fishing.* The fishery for whales, when conducted at the margin of those wonderful sheets of solid ice, called fields, is, when the weather is fine and the refuge for ships secure, of all other situations which the fishery of Greenland presents, the most agreeable and sometimes the most productive. A fish struck at the margin of a large field of ice, generally descends obliquely beneath it, takes four to eight lines from the fast-boat, and then returns exhausted to the edge. It is then attacked in the usual way, with harpoons and lances, and is easily killed. There is one evident advantage in field fishing, which is this. When the fast-boat lies at the edge of a firm unbroken field, and the line proceeds in an angle beneath the ice, the fish must necessarily arise somewhere in a semicircle, described from the fast-boat as a centre, with a sweep not exceeding the length of the lines out ; but most generally it appears in a line extending along the margin of the ice, so that the boats, when dispersed along the edge of the field, are effectual and as ready for promoting the capture, as twice

the number of boats or more, when fishing in open situations; because, in open situations the whale may arise anywhere within a circle, instead of a semicircle, described by the length of the lines withdrawn from the fast-boat. In consequence of this, it frequently happens that all the attendant boats are disposed in a wrong direction, and the fish, recovers its breath, breaks loose, and escapes before any of them can secure it by a second harpoon. Hence, when a ship fishes at a field, with an ordinary crew, and six or seven boats, two of the largest fish may be struck at the same time with every prospect of success, while the same force attempting the capture of two at once, in an open situation will, not unfrequently, occasion the loss of both. There have indeed been instances of a ship's crew, with seven boats, striking at a field, six fish at the same time, and of success in killing the whole. Generally speaking, six boats at a field are capable of performing the same execution, as near twice that number in open situations. Besides, fields sometimes afford an opportunity of fishing, when in any other situation there can be little or no chance of success, or, indeed, when to fish elsewhere is utterly impracticable. Thus calms, storms, and fogs, are great annoyances in the fishery in general, and frequently prevent it altogether; but at fields the fishery goes on under any of these disadvantages. As there are several important advantages attending the fishery at fields, so, likewise, there are some serious disadvantages, chiefly relating to the safety of the ships engaged in the occupation. The motions of fields are rapid, various, and unaccountable, and the power with which they approach each other and squeeze every resisting object, immense,—hence occasionally vast mischief is produced, which it is not always in the power of the most skilful and attentive master to foresee and prevent.

Thin fields, or fields full of holes, are usually avoided, because a 'fast fish,' retreating under such a field, can respire through the holes in the centre as conveniently as on the exterior; and a large fish usually proceeds from one hole to another, and if determined to advance cannot possibly be stopped. In this case all that can be done is,

to break the line or draw the harpoon out. But when the fish can be observed 'blowing,' in any of the holes in a field, the men travel over the ice and attack it with lances, pricking it over the nose, to endeavor to turn it back. This scheme, however, does not always answer the expectation of the fishers, as frequently the fear of his enemies acts so powerfully on the whale, that he pushes forward to the interior, to his dying moment. When killed, the same means are used as in pack fishing, to sink it, but they do not always succeed; for the harpoon is frequently drawn out, or the line broken in the attempt. If, therefore, no attempt to sink the fish avails, there is scarcely any other practicable method of making prize of it, (unless when the ice happens to be so thin that it can be broken with a boat, or a channel readily cut in it with an ice saw,) than cutting the blubber away, and dragging it piece by piece, across the ice to the vessel, which requires immense labor and is attended with vast loss of time. Hence, we have a sufficient reason for avoiding such situations whenever fish can be found elsewhere. As connected with this subject, I cannot pass over a circumstance which occurred within my own observation, and which excited my highest admiration.

On the 8th of July, 1813, the ship *Esk*, lay by the edge of a large sheet of ice, in which were several thin parts, and some holes. Here a fish being heard blowing, a harpoon, with a line connected to it, was conveyed across the ice, from a boat on guard, and the harpooner succeeded in striking the whale at the distance of 350 yards from the verge. It dragged out ten lines, (2400 yards) and was supposed to be seen blowing in different holes in the ice. After some time it happened to make its appearance on the exterior, when a harpoon was struck at the moment it was proceeding again beneath. About a hundred yards from the edge it broke the ice where it was a foot in thickness, with its crown, and respired through the opening. It then determinately pushed forward, breaking the ice as it advanced, in spite of the lances constantly directed against it. It reached, at length, a kind of basin in the field, where it floated on the surface of the water, without any incumbrance from

ice. Its back being fairly exposed, the harpoon, struck from the boat on the outside, was observed to be so slightly entangled that it was ready to drop out. Some of the officers lamented this circumstance, and expressed a wish that the harpoon were better fast; observing, at the same time, that if it should slip out, the whale would either be lost, or they would be under the necessity of cutting it up where it lay, and of dragging the pieces of blubber over the ice to the ship; a kind and degree of labor which every one was anxious to avoid. No sooner was the wish expressed, and its importance made known, than one of the sailors, a smart and enterprising fellow, stepped forward and volunteered his services to strike it better in. Not at all intimidated by the surprise which was manifested in every countenance, by such a bold proposal, he pulled out his pocket knife, leaped upon the back of the living whale, and immediately cut the harpoon out. Stimulated by this courageous example, one of his companions proceeded to his assistance. While one of them hauled upon the line and held it in his hands, the other set his shoulder against the extremity of the harpoon, and though it was without a stock, he contrived to strike it again into the fish more effectually than it was at first; the fish was in motion before they finished. After they got off its back it advanced a considerable distance, breaking the ice all the way, and survived this uncommon treatment ten or fifteen minutes. This admirable act was an essential benefit. The fish fortunately sunk spontaneously after being killed, on which it was hauled out to the edge of the ice by the line, and secured without further trouble. It proved a stout whale, and an acceptable prize.

Fishing in Crowded Ice or in Open Packs. — In navigable open drift ice, or among small detached streams and patches, either of which serve in a degree to break the force of the sea, and to prevent any considerable swell from arising, we have a situation which is considered as one of the best possible for conducting the fishery in; consequently, it comes under the same denomination as those favorable situations, in which I have first attempted to describe the proceedings of the fishers

in killing the whale. But the situation I now mean to refer to, is, when the ice is crowded and nearly close ; so close, indeed, that it scarcely affords room for boats to pass through it, and by no means sufficient space for a ship to be navigated among it. This kind of situation occurs in somewhat open packs, or in large patches of crowded ice, and affords a fair probability of capturing a whale, though it is seldom accomplished without a considerable degree of trouble. When the ice is very crowded, and the ship cannot sail into it with propriety, it is usual to seek out for a mooring to some large mass of ice, if such can be found, extending two or three fathoms or more under water..

A piece of ice of this kind, is capable not only of holding the ship 'head-to-wind,' but also to windward of the smaller ice. The boats then set out in chase of any fish which may be seen ; and when one happens to be struck, they proceed in the capture in a similar manner as when in more favorable circumstances, excepting so far as the obstruction which the quality and arrangement of the ice may offer, to the regular system of proceeding. Among crowded ice, for instance, the precise direction pursued by the fish is not easily ascertained, nor can the fish itself be readily discovered on its first arrival at the surface, after being struck, on account of the elevation of the intervening masses of ice, and the great quantity of line it frequently takes from the fast-boat. Success in such a situation, depends on the boats being spread widely abroad, and on a judicious arrangement of each boat, or a keen look out on the part of the harpooners in the boat, and on their occasionally taking the benefit of a hummack of ice, from the elevation of which the fish may sometimes be seen 'blowing' in the interstices of the ice ; or pushing or rowing the boats with the greatest imaginable celerity, towards the place where the fish may have been seen ; and, lastly, on the exercise of the highest degree of activity and despatch in every proceeding.

If these means be neglected, the fish will generally have taken his breath, renewed his strength, and removed to some other quarter, before the arrival of the boats ; and it is often remarked, that if there be one part of the

ice more crowded or more difficult of access than another, it commonly retreats thither for refuge. In such cases, the sailors find much difficulty in getting to it with their boats; having to separate many pieces of ice before they can pass through between them. But when it is not practicable to move the pieces, and when they cannot travel over them, they must either drag the boats across the intermediate ice, or perform an extensive circuit, before they can reach the opposite side of the close ice into which the whale has retreated. A second harpoon, in this case, as indeed in all others, is a material point. They proceed to lance whenever a second harpoon is struck, and strike more harpoons as the auxiliary boats progressively arrive at the place.

Fishing in Storms. Except in situations sheltered from the sea by ice, it would be alike useless and presumptuous to attempt to kill whales during a storm. Cases, however, occur, wherein fish that were struck during fine weather, in winds which do not prevent the boats from plying about, remain entangled, but unsubdued, after the commencement of a storm. Sometimes the capture is completed, at others, the fishers are under the necessity of cutting the lines, and allowing the fish to escape. Sometimes, when they have succeeded in killing it, and in securing it during the gale, with a hawser to the ship, they are enabled to make a prize of it on the return of moderate weather; at others, after having it to appearance secured, by means of a sufficient rope, the dangerous proximity of a pack of ice constrains them to cut it adrift and abandon it, for the preservation of their vessel. After thus being abandoned, it becomes the prize of the first who gets possession of it, though it be in the face of the original captors. A storm commencing while the boats are engaged with an entangled fish, sometimes occasions serious disasters. Generally, however, though they suffer the loss of the fish, and perhaps some of their boats and materials, yet the men escape with their lives.

Fishing in Foggy Weather. The fishery in storms, in exposed situations, can never be voluntary, as the case only happens when a storm arises subsequent to the time

of a fish being struck ; but in foggy weather, though occasionally attended with hazard, the fishery is not altogether impracticable. The fogs which occur in the icy regions in June and July, are generally dense and lasting. They are so thick, that objects cannot be distinguished at the distance of 100 or 150 yards, and frequently continue for several days without attenuation. To fish with safety and success, during a thick fog, is, therefore, a matter of difficulty, and of still greater uncertainty. When it happens that a fish conducts itself favorably, that is, descends almost perpendicularly, and on its return to the surface remains nearly stationary, or moves round in a small circle, the capture is usually accomplished without hazard or particular difficulty ; but when on the contrary it proceeds with any considerable velocity in a horizontal direction, or obliquely downwards, it soon drags the boats out of sight of the ship, and shortly so confounds the fishers in the intensity of the mist, that they lose all traces of the situation of their vessel. If the fish, in its flight, draws them beyond the reach of the sound of a bell or a horn, their personal safety becomes endangered ; and if they are removed beyond the sound of a cannon, their situation becomes extremely hazardous, especially if no other ships happen to be in the immediate vicinity. Meanwhile, whatever may be their imaginary or real danger, the mind of their commander must be kept in the most anxious suspense, until they are found ; and whether they may be in safety, or near perishing with fatigue, hunger, and cold, so long as he is uncertain, his anxiety must be the same. Hence it is, that feelings excited by uncertainty, are frequently more violent and distressing, than those produced by the actual knowledge of the truth.

Such are the methods by which, according to Scoresby, this monster of the deep is compelled to submit to the very far inferior force of man. The dangers attending this occupation have a peculiar effect upon those engaged in it. They awaken in their breasts a most ardent interest in the employment. The excitement produced by the chase, and the congratulation and enjoyment resulting from the victory, are scarcely equalled by any other

human pursuit. It must be remembered that the capture of every whale shortens the voyage. The ship is to remain upon the station until her cargo is completed ; and of course the sailor sees in every victory, that the time of his return to country and home draws nigh. This consideration produces no trifling effects, as we may easily conceive, by taking into consideration the length and the distance of the voyages.

Besides, it is, in this country we believe, the uniform practice to allow every sailor a *share* of the *cargo* for his pay. This makes the business a common cause. In fact, it would probably be difficult or impossible to manage so laborious and hazardous a business, with any proper degree of spirit, in any other way. Upon this plan of allowing each sailor a regular share of the profits, each one considers every captured whale as in part *his* property. He pursues him with the spirit and energy which a man feels who is toiling for himself, and during the return voyage he feels the interest of an owner in the ship and cargo. He is joint owner. The valuable commodities which his skill and courage have procured, are in part *his property* and he inquires with eager interest, on his landing, into the state of the market, — the price of the whalebone and oil ; for the pecuniary result of the voyage, to him, is not decided till the cargo is sold. So completely does the system identify the interest of the sailor with the final success of the enterprise.

In a future number we may pursue this subject, by describing the processes in this business, *subsequent* to the capture of the whale.

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SCIENTIFIC TRACTS.

NUMBER XIX.

MAN, PHYSICALLY CONSIDERED.

I. — THE PECULIARITIES WHICH DISTINGUISH MAN FROM ALL OTHER ANIMALS.

‘THE physical organization of man, while it subjects him to those laws of generation, growth and dissolution, which extend to all orders of living nature, bears at the same time, in each of its parts, and as a whole, a character so peculiar, so extraordinary and so sublime, that it is impossible to suppose even the most distant relationship between the brutes, who do nothing but feed and propagate on the surface of the earth, and him who is born to exercise dominion over them. That upright and elevated part, which indicates both dignity and courage; those hands, the trusty instruments of our will, the dexterous performers of the most magnificent, as well as the most useful works; those eyes uplifted from the dust, whose intelligent glance can survey the immensity of the heavens; those organs which enable us to express thought by articulate sounds of endless variety; the admirable union of strength and suppleness in all our members; finally the harmony and perfectibility of all our senses, assign to us the first rank among living beings, and give us both the right to claim and the power to hold the empire of the earth.

‘Anatomy and physiology have placed these truths beyond the reach of dispute. Those naturalists who have pretended to confound the human species with that of monkeys, notwithstanding the essential difference in

the feet, in the organs of speech, and the notes of the voice, appear to recognise no fixed principles whatever in their classification of the species of animals.*

Strange as it may seem, many persons have attempted to confound mankind with monkeys, supposing them to compose one and the same species. And as one horse is better — of more perfect form, and noble appearance than another, so are some monkeys who are called men superior in instinct and in appearance to their brethren who are chattering in the woods. A tail is a very convenient appendage to the monkeys of the woods, but Lord Monboddo supposes that civilization having introduced the custom of *sitting down*, this appendage has been worn off. The stories that have been told of the Ourang Outang, and of his striking resemblance to the human race are greatly exaggerated. This native of the tropical forests is a disgusting little animal running upon all fours, but capable of being taught, like the dog, to stand erect. This is never his natural attitude, and the anatomical structure of his limbs, renders it impossible that it should be. This animal is made for climbing, and its feet are constructed in such a manner as to enable it to grasp hold of the branches. It is covered with coarse hair, and has features but little more resembling the human than the dog. And this is the disgusting creature with which some of our fellow men have claimed relationship.

Many marvellous stories have been related of wild men found in the woods who were unable to speak, who run upon all fours, and ascended trees with the swiftness of the wild-cat. But not one of these stories are well authenticated. A slave ship was once wrecked upon the coast of France. One of the negro girls swam ashore, the rest of the crew were lost. She was found in the woods. As she had just been brought from the wilds of Africa, she of course could not converse in French, and people thought she could not talk at all. Wonderful stories were told about her. She was however, instructed in the French language by the hospitable family, into

* Malte Brun.

whose hands she fell, and was thus enabled to give an account of herself, and thus put to flight the dreams of those self-called philosophers, who would infer that the natural state of man was like that of the monkey, without speech, and without reason. Voltaire says that if any one wishes to learn the habits of the *bee*, he will not take a solitary one that has wandered from the hive and is lost, and neither should we, in learning the nature and the habits of man, take an individual who from some unknown cause has been thrown off from his companions, and wanders alone in the solitude of the forest. And yet from a few fanciful stories, like that of the young negress just related, Monboddo and Rousseau, followed by a retinue of admiring disciples, have inferred that man and the monkey are of the same species. Says Monboddo, 'the Ourang Outangs are proved to be of our species, by marks of humanity that I think are incontestable.' 'This truly is not a very complimentary conclusion. Rousseau states this idea in terms still more revolting. 'All these varieties which a thousand causes have produced and are producing, lead me to believe, that many animals which voyagers have taken for brutes, because there was some difference in their exterior conformation, or because they could not speak, were in reality savage men whose race has been for a long period dispersed in the woods, and have had no occasion to develop any of their virtuous faculties, and have acquired no degree of perfection, but remain in the primitive state of nature.' The gentlemen therefore, who shoots a monkey in the forest of Borneo sheds the blood of his fellow man, and by the laws both of God and man is a murderer.

The pretended facts which are adduced in support of this theory are unsatisfactory and trifling in the extreme. The history of Peter the wild boy, is one of the most authentic cases.

In July, 1724, Jurgen Mayer was walking in his field in Hanover, and found a naked black haired boy about twelve years of age. The boy did not seem much afraid of him, and the man by showing him two apples enticed him home and secured him. He could not speak. Apparently he had lived for some time in the woods, upon

berries and roots. The children in the town when they first saw him called him Peter, and he ever afterwards went by that name. He appeared nearly destitute of sense — did not like bread, but would eat grass, bean shells, and the peeling of green sticks. He was very averse to any clothing, but soon became accustomed to it. Monboddo and Rousseau were in raptures when they heard of the discovery of this wild boy. They considered him the true child of nature — man in his genuine, and unsophisticated state. Monboddo says, 'I consider his history as a brief chronicle, or abstract of the history of the progress of human nature, from the mere animal to the first stage of civilized life.' About this time metaphysicians were in a warm controversy respecting innate ideas, and this poor boy was entrusted to the care of Dr Arbuthnot, that he might watch the development of his innate ideas and thus determine the question.

But unfortunately some subsequent facts came to light which put to flight all their hopes. It seems that when he was first met a small fragment of a shirt hung about his neck; and the whiteness of one part of his body contrasted with the brownness of other parts, proved that he must have worn trowsers, though not stockings. Some boatmen descending the river Weser, upon whose banks he was found, had several times seen a poor naked boy and had given him food. By following up these inquiries, at length it was ascertained, this child was born an idiot and dumb, — that he once was lost in the woods for some time and again returned home. Upon his father's second marriage, a cruel stepmother drove him again from home. And this poor idiot was made the foundation of an argument intended to elevate the monkey and to degrade mankind.

Some *philosophers*, have gone even farther than this. They claim affinity with the oyster! As we retrace the line of our ancestry we are landed in the humble origin of a bed of oysters. How are the mighty fallen! 'Dr Darwin* seriously conjectures that as aquatic animals

* Dr Erasmus Darwin was born at Newark, in Nottinghamshire, 1732. He was a man of liberal education; devoted himself particu-

appear to have been produced before terrestrial, and every living substance to have originated from a form of nucleus exquisitely simple and minute, and to have been perpetually developing and expanding its powers, and progressively advancing towards perfection. Man himself must have been of the aquatic order on his first creation, at that time indeed imperceptible from his exility, but in process of years or rather of ages, acquiring a visible or oyster like form, with little gills instead of lungs, and like the oyster produced spontaneously, without distinction into sexes; that as reproduction is always favorable to improvement, the aquatic or oyster mannikin, by being progressively accustomed to seek its food on the nascent shores or edges of the primeval ocean, must have grown, after a revolution of countless generations, first into an amphibious, and then into a terrestrial animal; and in like manner, from being without sex, first also into an androgynous* form, and thence into distinct male and female.' What a blessing it is to the world, that some hungry man, did not in ages which are past, swallow for his dinner, Sir Isaac Newton's oyster parents!

Such are theories which have been advocated in contradiction to the simple account of the sacred historian. How puerile and ridiculous do they appear when contrasted with the beautiful simplicity of the Bible. It is there stated that God created Adam and Eve, and from them the whole human family has descended. And yet will men for the sake of furnishing arguments against the Bible, acknowledge the baboon for their brother and the clotted oyster for their father. They call this philosophy and science — breaking away from the shackles of superstition.

Such speculations as these only deserve notice to show into what wild vagaries the human mind may wan-

larly to the study of physics, and wrote largely upon that subject. He also wrote some verses of no inconsiderable elegance and beauty. As a physician he acquired great celebrity, and all his philosophical works show a mind strong and enriched with reading, but wild and fanciful. He died suddenly at Derby, in 1802.

* *Androgynous*. Uniting both sexes.

der, even under a state of high cultivation. Nothing can be more evident than that the human race, is totally distinct from all other animals. Says Lawrence, 'the human species has numerous distinctive marks, by which under every circumstance of deficient or imperfect civilisation, and every variety of country and race, it is separated by a broad and clearly defined interval from all other animals.'

The following circumstances are abundantly sufficient to characterise man, and distinguish him from all other animals.

1. *Smoothness of skin.* There is no animal but man, who is not furnished by its Creator with natural clothing. Stories have been told of hairy nations, but they are unfounded. A smooth skin is peculiar to the human family. The monkey and the ourang outang, who have so frequently and with such little cause been compared with man, are nearly covered with hair, and no parts of their bodies present any resemblance to the human face.

2. *Erect Stature.* Man alone has an anatomical structure which makes the erect posture natural to him. The dog and the monkey and some other animals may be taught to stand upon their hind legs, but this position is about as unnatural to them, as it would be for a man to stand upon his hands. No nation, or tribe, or healthy individual has ever yet been found with whom the upright attitude was not natural. Whenever we find a race of men running upon all fours, and a tribe of monkeys walking erect, we will admit the claims of relationship.

3. *Possession of two hands.* The monkey is sometimes said to be four handed, instead of four footed. 'They live chiefly in trees for which they are admirably adapted by having prehensile members, instruments for grasping and holding on both upper and lower extremities. They live in trees and find their food in them; they can hang by one fore or hind leg, employing the remaining number in gathering fruit or in other offices.' The perfection of the formation of the human hand, characterises man. He is the only two handed animal.

4. *Speech.* Several animals may be taught to pro-

nounce words and even sentences. But their mimicry of human sound cannot be called speech. They may articulate, but they are incapable of forming ideas and communicating them by language. Man alone possesses this noble faculty, corresponding to his elevated, physical, moral and intellectual powers. No race of savages was ever yet discovered who had not a language framed for enlarging and communicating ideas. And thus is man distinguished from the brute.

5. *Capability of inhabiting all climates.* Man is the only animal which can live and multiply in every country, upon the surface of the globe. Some animals are confined to the polar ice; others to the temperate regions; others can only live beneath the blazing rays of the torrid zone. Man scales the high mountain, and spreads his tent upon the desert, and erects his dwelling in the deep valley. He is healthy and vigorous under the burning line, and braves the wintry tempest of the arctic circle. All countries and all parts of the globe, afford a dwelling-place for man. This power is possessed by no other animal.

6. *Man is omnivorous.* As man is capable of enduring the extremes of heat and cold in all climates, so can he in all countries find food, capable of affording him nourishment and support. The brute creation are very much limited in the sources from which they can derive nourishment. To man there is hardly any limit. The herbs of the field, and the fowls of the air, and the fishes of the sea, and the beasts of the earth, alike contribute to the strength and perfection of his corporeal powers. Among the eternal snows of the north, man lives upon animal food alone; upon the luxuriant plains of India, the human frame is supported by vegetable aliment.

7. *Intellectual Powers.* The Creator has given all animals certain instincts by which their lives are preserved. And as there is a vast difference in the physical organization of these animals, so is there a vast difference in the perfection of their instincts. It is difficult to define the difference between instinct and reason, but when we look at the effects, the difference is very manifest. 'The most stupid man is able to manage the most

alert and sagacious animal ; he governs it and makes it subservient to his purposes. This he effects not so much by bodily strength or address, as by the superiority of his intellectual nature. He compels the animal to obey him by his power of projecting and acting in a systematic manner. The strongest and most sagacious animals have not the capacity of commanding the inferior tribes, or of reducing them to a state of servitude. The stronger indeed devour the weaker ; but this action implies an urgent necessity only, and a voracious appetite ; qualities very different from that which produces a train of actions all directed to one common design. If animals be endowed with this faculty, why do not some of these assume the reins of government over others, and force them to furnish their food, to watch for them, and to relieve the sick or wounded ? But among animals there is no mark of subordination, nor indication that any one is able to recognise or feel a superiority in his nature above that of other species. We should, therefore, conclude that all animals are in this respect of the same nature, and that the nature of man is not only far superior, but likewise of a very different kind from that of the brute.

Such are some of the more prominent characteristics peculiar to man. Others might be adduced from his external and internal structure, but the above are amply sufficient to induce us to assign to him a specific distinction.

II. — THE PECULIARITIES OF THE SEVERAL NATIONS AND TRIBES OF MEN.

As we take a general survey of the human species, we are struck with astonishment, at the vast difference which appears in the physical constitution, and moral condition of various nations. In color, in height, in bodily formation there is a great dissimilarity. The Patagonian and the Caffre are seldom less than six feet tall, and not unfrequently they rise to nearly seven feet. There are other nations where you seldom find an individual exceeding five feet in height. The inhabitants of Lapland, and the Esquimaux are said to be real dwarfs,

their stature being commonly only four feet. 'Observe the delicate skin and the exquisite rose and lily, that beautify the face of the Georgian or Circassian, contrast them with the coarse skin, and greasy blackness of the Hottentot, and imagination is lost in the discrepancy. Take the nicely turned and globular form of the Georgian head, or the elegant and unangular oval of the Georgian face; compare the former with the flat skull of the Carib, and the other with the flat visage of the Mogul Tartar; and it must at first sight be difficult to conceive that each of these could have proceeded from one common source.' The diversities of moral and intellectual condition are perhaps still greater. Look at the accomplished scholar of enlightened lands — the eloquent orator who draws down the thundering applause of intelligent delight; and compare him with the naked savage dozing in the filth of his smoky cabin. Look at the Christian bowing at the shrine of Jehovah, living a life of prayer and faith, and animated with the hopes of immortality; and then look at the fierce and loathsome cannibal, tearing with bloody teeth, the quivering limbs of his human victim. How vast the difference!

In consequence of this great diversity in the condition and appearance of our race, it has been found convenient to classify the human form. A convenient classification is presented by the five grand sections into which the globe is divided by geographers. These five classes have received different names.

<i>Geographical Division.</i>	<i>Blumenbach's* Division.</i>	<i>Gmelin's Division.</i>
1. European Race.	Caucasian.	White Man.
2. Asiatic Race.	Mongolian.	Brown Man.
3. American Race.	American.	Red Man.
4. African Race.	Ethiopian.	Black Man.
5. Australian Race.	Malay.	Tawny Man.

* Blumenbach is a German naturalist of very great celebrity. For the last fiftyfive years he has been lecturing at Gottingen upon the subjects of natural history, physiology, osteology, comparative anatomy and pathology. He is justly esteemed one of the brightest ornaments of the far famed university at that place. All his works bear the impress of genius, and perhaps no man has contributed more richly to the advancement of those sciences upon which he has

These divisions embrace precisely the same class — the names only are different. I shall adopt the nomenclature of Blumenbach, as that is the most common, and generally the most highly esteemed.

1. *Caucasian*. This is the most elegant variety of the human form. The characters of this race are 'a white skin, either with a fair rosy tint or inclining to brown; red cheeks; hair black, or of the various lighter colors, copious, soft, and generally more or less curled, or waving. The head globular, the face straight and oval, with the features moderately distinct; the forehead slightly flattened; the nose narrow and slightly aquiline; the cheek bones unpronounced; the mouth small; the lips a little turned out, especially the under one; the chin full and rounded; the eyes variable, but for the most part blue.' The name of this variety is derived from Mount Caucasus, which is supposed to have been the original abode of this class. Under this class all the Europeans, except the Laplanders are included, the inhabitants of western Asia, and all the the inhabitants of America, who have descended from European ancestors. In this variety, there are very various and strongly marked modifications. They are by no means alike in physical or moral traits. There is merely a general resemblance sufficiently marked to admit of classification. Blumenbach supposes that the primitive form of the human race was that which belongs to the Caucasian variety. With this variety we find the most moral and intellectual cultivation; they compose the enlightened nations of the earth, and though individuals of other classes have risen to moral and intellectual eminence, have shed lustre on art and science, yet this class is now very decidedly in the advance of all the rest.

2. *Mongolian*. This variety is characterised by a yellowish brown or olive complexion, with black eyes, and hair black, straight, coarse, and thin. The red tint is never seen in the cheek. The head instead of being globular like the Caucasian is nearly square. The

so ably lectured. In 1826 he was lecturing with unabated industry. I am not certain whether he is now living or not. If he is, he is now about eighty years of age.

forehead is low, and the face broad and flat, with features nearly running together; the cheek bones wide and projecting; the chin prominent with large ears and thick lips. In general the stature of this race is inferior to that of the Caucasian. This class includes the tribes of central and northern Asia; the Laplanders and the tribes of Esquimaux in the northern part of America.

3. *The American.* This variety includes all the aboriginal inhabitants of the American continent excepting the Esquimaux. This class is characterised by a dark orange, or copper colored skin; the hair is black, thick and coarse; the cheek bones high and expanded; the eye deeply seated, the forehead low, and the upper part of the face broad; the general expression of countenance and the form of the head much resembles the Mongolian tribes. 'In the natives of Nootka Sound,' says Cook, 'the visage of most is round and full, and sometimes also broad, with high prominent cheeks; and above these the face is frequently much depressed, or seems fallen in quite across between the temples; the nose also flattening at its base, with pretty wide nostrils and a rounded point.' 'This variety appears to be composed of several classes very considerably differing from each other. With some the complexion is almost white, with others almost black. It has by some been asserted that these tribes have no beard, but this is incorrect. They all have beards, but it is weak, and many of them pluck it out by the roots.

4. *Ethiopian.* The characteristics of this variety are very distinctly defined. They are, hair black and woolly; head long and narrow; projecting cheek bones; eyes prominent; the nose broad, thick, flat and confounded with the upper jaw; the front teeth obliquely placed; the lips very thick; the chin recedes, and the knees in many instances turn in. This variety is found all over western and southern Africa; upon the coast of Madagascar and New Holland, and in the islands of Van Diemens land, New Caledonia and New Guinea. Indeed negro tribes have been found in all the regions of the torrid zone except America. There are however diver-

sities in this class. The real negro has a complexion of jet, and crisped hair; the Caffre has a copper complexion, and long woolly hair; the natives of Van Diemens land, a color of soot with frizzled hair. The Hottentots also, who are included in this class, resemble the Malay variety, in the shape of their heads, and the Mongolians in their complexions and thin beards; but their woolly hair gives them a place in the Ethiopian class.

5. *The Malay.* The characteristics of this variety are very indefinite and uncertain. Their color varies from a very light brown, almost to a black; the hair is black, very abundant, short and curled; the head narrow, with a prominent forehead; the mouth large; nose thick and flattened. Under this variety are included races of men very different indeed, but too imperfectly known at present to admit of a satisfactory arrangement. The inhabitants of New South Wales, and of the numerous clusters of islands in its vicinity, and also of the unnumbered islands scattered through the South Sea, belong to this division.

It will at once be perceived that this classification is exceedingly imperfect. You will find individuals in each of these classes who might with perfect propriety be in any of the other. All you can say is that there is a general resemblance. If a person should endeavor to divide the inhabitants of any town into two classes, placing all the light complexioned in one class and the dark complexioned in the other, it is evident that there would be many persons, whom it would be difficult to know to which class to assign. The two classes run into each other; the difference is not broadly marked. And thus it is in these five classes into which the whole human family is for convenience' sake arranged. There are no natural and clearly defined limits. There is a mingling of shades; an imperceptible gradation. Some naturalists have thought it necessary to make many more divisions than the five above enumerated, while others have thought that three classes would afford sufficient discrimination; and therefore have contracted the varieties into three — the European, the Asiatic, and the African.

Such is the general classification of the human race.

It will be perceived that the varieties of form, color, stature, &c, are by no means small. The dwarfish Esquimaux, and the gigantic Patagonian, the jet black African and the fair faced European, seem widely separated from each other. But there are intervening links; these widely different hues mingle and blend. Many exaggerated stories have been told of the human stature reaching ten and even eighteen feet. There is a very common belief that the human stature in remote ages, was greater than at the present time, and this belief has been grounded upon accounts which have been given of gigantic bones dug up. We are not warranted, however, in believing in the general degeneracy of the human frame. No well authenticated example can be adduced of man's stature exceeding eight or nine feet. We must however except Goliath of Gath. He was in height six cubits and a span. The scripture cubit is said to have been twentyone inches. This makes this vaunting Philistine to have had the enormous stature of eleven feet and four inches. This computation cannot however be relied upon as perfectly accurate, for we cannot ascertain the precise measurement of the scripture cubit. It is however undoubtedly very near the truth. Habcut, a celebrated anatomist, describes some huge bones found in a sepulchre, near the ruins of a castle, which he says composed a skeleton twentyfive feet and a half high and ten feet broad at the shoulders. This statement gave rise to a long and warm controversy, at the close of which it remained undecided whether these bones were the remains of a man, or an elephant. The latter is altogether the most probable. There are, however, several well authenticated accounts of very great stature.

One of the king of Prussia's guards measured eight feet and a half. J. H. Reichardt was eight feet and three inches. There is now in England, in one of the college museums, the skeleton of an individual who was eight feet and four inches. Several Irishmen have also been exhibited in London rising of eight feet. Generally these giants have not possessed symmetry of form, or strength proportioned to their size. And it is a very

common observation that large men are seldom noted for great intellectual powers.

There are other individuals who fall as far short of the ordinary stature, as those above alluded to exceed it. There are not only individuals dwarfs, but large tribes exceedingly diminutive in size. The Bojisman tribe in south Africa, are remarkably short. About four feet six inches is said to be the average size of the men, and four feet that of the women. Barrow says he saw one woman measuring but three feet and nine inches, who had several children. How strong the contrast between such a tribe as this, and the Patagonians, whose average height is said to be from six feet and a half to seven feet.

Buffon and many learned naturalists have advanced the idea that the soil and climate of America is unfavorable to the development of the bodily powers. They think that men and brutes have dwindled here, and will continue to dwindle. They describe the aboriginal inhabitants of this country as necessarily dwarfish, weak and puny. And some of the literary nobility of the old world, have followed out this idea to a still more discouraging results. They say that the human mind here cannot expand — that there are some causes operating in this continent to cramp genius, and enervate the intellectual powers. Lawrence scouts at this idea, and yet goes on to say, 'to expect that the native Americans or Africans can be raised by any culture, to an equal height in moral sentiments and intellectual energy with Europeans, appears to me quite as unreasonable, as it would be to hope that the bull dog may equal the greyhound in speed; that the latter may be taught to hunt by scent like the hound; or that the mastiff may rival in talents and acquirements, the sagacious and docile poodle.' In direct opposition to this statement are arranged many facts which prove that the benighted savage, when under circumstances favorable for the development of his intellectual powers, may rise to virtue and to eminence. Our own ancestors were as degraded as any tribe of savages now howling in the wilderness. They are described as naked barbarians, fierce and cruel, with bodies smeared with paint and living by

violence. Says Gibbon, 'when they hunted the woods for prey, it is said they attacked the shepherd rather than his flock; and that they curiously selected the most delicate and brawny parts both of males and females, which they prepared for their horrid repast. If in the neighborhood of the commercial and literary town of Glasgow, a race of cannibals has really existed, we may contemplate in Scottish history the opposite extremes of savage and civilized life. Such reflections tend to enlarge the circle of our ideas; and to encourage the pleasing hope that New Zealand may produce in some future age, the Hume of the southern hemisphere.' What is it that has raised us to such comparative refinement and intelligence? It is the operation of the same causes which are now sweeping the clouds from benighted Africa, and demolishing the bloody temples of India and pouring the light of truth and love upon the long desolated shores of Hawaii. It is the blessed religion of Jesus Christ, proclaiming love to God and love to man.

III. — THE CAUSES OF THE VARIETIES OF THE HUMAN SPECIES.

The question has been asked by many who have observed the great diversity in the human family, Are these all brethren? have they descended from one stock? or must we trace them to more than one? and if so, how many Adams must we admit? Upon this subject we have no history but that given by Moses. Says Dr Good, 'the only fair and explicit interpretation that can be given to the Mosaic history, is that the whole human race has proceeded from one single pair, or in the words of another part of the sacred writings "God made of one blood all nations of men, for to dwell upon all the face of the earth." The book of nature is in this, as in every other respect, in union with that of revelation; it tells us that one single pair must have been adequate to all the purposes on which some philosophers have grounded their objections; and it should be further observed to them that thus to multiply causes without ne-

cessity, is not more inconsistent with the operations of nature, than with those of genuine philosophy.' It is a little remarkable that those who are dissatisfied with the simple and natural narration of the inspired writers should have adopted theories in such extremes of opposition to each other. Some of these philosophers, among whom are to be found the respectable names of Linnæus, Buffon, and Helvetius, respectable certainly as to scientific attainments, think we can trace back our ancestral line to the filthy and chattering baboon. Others, with Darwin at their head, make the oyster shell our cradle. Others think we cannot all be traced back even to Adam, but that at the commencement of human existence, many couples were created answering to the diversities which we now see. While Moses, writing under the inspiration of the Almighty, says that God first created Adam and Eve, and from them all the inhabitants of the world have descended. How much more simple and philosophical this account, than the wild vagaries of Buffon and of Darwin. Voltaire says, 'no one but a blind man can doubt that the whites, the negroes, the Albini, the Hottentots, the Laplanders, the Chinese, and the Americans compose races entirely distinct.' Why these nations alone? 'There are striking marks of difference between innumerable other tribes, and these all run into each other by imperceptible gradation. If we adopt the idea that there must have been originally more than one couple, to account for the present variety of the human species, *how many* distinct fountains must we suppose to have been, from whence the streams of nations have flowed? It is as difficult to account for the present variety, if we suppose fifty or a hundred, as if we suppose one. 'In describing the varieties, it is necessary to fix on the most strongly marked tints, between which there is every intermediate shade of color. The opposite extremes run into each other by the nicest and most delicate gradations; and it is the same in every other particular in which the various tribes of the human species differ. This forms no slight objection to the hypothesis of distinct species; for on that supposition we cannot define their number, nor draw out the boundaries

that divide them. Neither does the color, which belongs to any particular race, prevail so universally in all the individuals of that race, as to constitute an invariable character, as we should expect if it rose from a cause so uniform as an original specific difference. Its varieties on the contrary, point out the action of other circumstances.'

It is impossible fully to explain the causes of the great diversity now to be seen. Climate, soil, manners and customs have a great influence, but we cannot see precisely how they operate in producing given effects. There is however precisely the same difficulty in accounting for the different features of members of the same family, that there is in accounting for the varieties of the human race. Why do the same parents have one child with a light complexion, and light hair; and another with a dark complexion, and dark hair? No one can tell. We know that children of different appearance are born of the same parents, — why then may not the Caucasian, the Ethiopian, the Mongolian, the American, and the Malay be traced back to the same common parents, Adam and Eve? Most evidently they may. True we cannot account in full for the causes of this difference; neither is it to be expected, for we cannot account for the causes of the difference in the children who encircle the same fire-side.

Various modes have been suggested by which these varieties might have been naturally produced. It is said that 'the heat of the climate is the chief cause of blackness among the human species. When this heat is excessive, as in Senegal and Guinea, the men are perfectly black; when it is a little less violent the blackness is not so deep; when it becomes somewhat temperate, as in Barbary, Mongolia, Arabia, &c, mankind are only brown; and lastly when it is altogether temperate, as in Europe and Asia, men are white. Some varieties, indeed, are produced by the mode of living. All the Tartars for example, are tawny; while the Europeans who live under the same latitude are white. This difference may safely be ascribed to the Tartars being always exposed to the air; to their having no cities or fixed habi-

tations ; to their sleeping constantly on the ground, and to their rough and savage manner of living. These circumstances are sufficient to render the Tartars more swarthy than the Europeans, who want nothing to make their life easy and comfortable. Why are the Chinese fairer than the Tartars, though they resemble them in every feature ? because they live in towns and practice every art, to guard themselves against the injuries of the weather ; while the Tartars are perpetually exposed to the action of the sun and air. Climate may be regarded as the chief cause of the different colors of men, but food, though it has less influence than climate, greatly affects the form of our bodies. Coarse, unwholesome and ill-prepared food makes the human species degenerate. All those people who live miserably are ugly and ill made. Even in France the country people are not so beautiful, as those who live in towns ; and I have often remarked in those villages, where the people are richer and better fed than in others, the men are likewise more handsome and have better countenances. The air and the soil have great influence on the figures of men, beasts and plants. Upon the whole, every circumstance concurs in proving that mankind are not composed of species essentially different from each other ; that on the contrary, there was originally but one species, which after multiplying and spreading over the whole surface of the earth, has undergone various changes by the influence of the climate, food, mode of living, epidemic diseases, and mixtures of dissimilar individuals ; that at first these changes were not conspicuous, and produced only individual varieties ; that these varieties became afterwards more specific, because they were rendered more general, more strongly marked and more permanent, by the continual action of the same cause ; that they are transmitted from generation to generation, as deformities or diseases pass from parents to children ; and that lastly, as they were originally produced by a train of external and accidental causes, and have only been perpetuated by time, and the constant operation of these causes, it is probable that they will gradually disappear, or at least that they will differ from what they

are at present, if the causes which produce them should cease, or if their operation should be varied by other circumstances and combinations.

‘The state of society is said to have great effect on the formation and color of the body. The nakedness of the savage, the filthy grease and paint with which he smears his body; his smoky hut, scanty diet, want of cleanliness, and the undrained and uncleared country which he inhabits not only darken his skin but render it impossible, that it ever should be fair. On the other hand the conveniences of clothing and lodging; the plenty and healthful quality of food; a country drained and cultivated, and freed from noxious effluvia; improved ideas of beauty; constant study of elegance, and the infinite arts for attaining it, even in personal figure and appearance, give cultivated an immense advantage over savage society, in its attempts to counteract the influence of climate, and to beautify the human form.’

‘In tracing the globe,’ says Smith, ‘from the pole to the equator, we observe a gradation in the complexion, nearly in proportion to the latitude of the country. Immediately below the arctic circle, a high and sanguine color prevails; from this you descend to a mixture of red and white; afterwards succeed the brown and the olive, the tawny, and at length the black, as you proceed to the line. The same distance from the sun, however, does not in every region, indicate the same temperature of climate. Some secondary causes must be taken into consideration as correcting and limiting its influence. The elevation of the land; its vicinity to the sea, the nature of the soil, the state of cultivation, the course of winds, and many other circumstances, enter into this view. Elevated and mountainous countries are cool, in proportion to their altitude above the level of the sea.’

It is stated by Lawrence, and is a well known fact, that ‘the color of the Europeans nearly follows the geographical position of countries. This part of the world is occupied almost entirely by a white race, of which the individuals are fairer in cold latitudes, and more swarthy and sunburnt in warm ones. Thus the French may be darker than the English, the Spaniards than the French,

and the Moors than the Spaniards. In the same way, where different parts of the country differ much in latitude and in temperature, the inhabitants may be browner in the south, than in the north ; thus the women of Grenada are said to be more swarthy than those of Biscay, and the southern than the northern Chinese. For a similar reason the same race may vary slightly in color, in different countries. The Jews, for example, are fair in Britain and Germany, browner in France and Turkey, swarthy in Portugal and Spain, olive in Syria and Chaldea. An English sailor who had been for some years in Nukaheiwah, one of the Marquesas islands, had been so changed in color, that he was scarcely to be distinguished from the natives.'

'It is in reality,' says Good, 'from long and deeply rooted habit alone that the black, red, and olive color of the Ethiopian, American and Moguls, is continued in the future lineage of so many generations, after their removal into other parts of the world, and that nothing will in general restore the skin to its original fairness, but a long succession of intermixtures with the European variety. It is a singular circumstance that the black color appears to form a less permanent habit, than the red or olive ; for the children of olive and copper colored parents, exhibit the parental hue from the moment of birth, but in those of blacks it is usually six, eight or ten months before the black pigment is fully secreted. We also sometimes find this not secreted at all, whence the anomaly of white negroes ; and sometimes only in interrupted lines, or patches, whence the anomaly of spotted negroes ; and we have even a few rare cases of negroes in America who in consequence of very severe illness have had the whole of the black pigment absorbed and carried off, and a white pigment diffused in its stead. In other words, we have instances of a black man being suddenly bleached into a white man. These instances are indeed of rare occurrence ; but they are sufficient to shew the absurdity of the argument for a plurality of human stocks or species, for a mere difference in the color of the skin ; an argument thus proved to be altogether superficial and which we may gravely assert to be not more than *skin deep*.

‘Though this reasoning will not fully explain all the varieties of human appearance, yet it is undoubtedly in general is correct. These causes are almost infinitely varied and combined, and consequently we find in every nation, village, and even family, striking diversities of complexion, form, and stature.’

Although, however, it may be admitted that all the races of men are of one family, it does not by any means follow that they are all *intellectually equal*. Many persons seeing, *as they suppose*, sufficient evidence of the inferiority in intellectual or physical power, of some of the races of men, have concluded that this is in itself a sufficient argument to disprove identity of origin. But a moment's reflection will show us that we are not compelled to maintain the intellectual equality of the different portions of the human family, simply because we hold that they descended from one pair. In the course of ages, the various collateral branches of the same stock may diverge from each other until in many traits both physical and intellectual, they become widely different, and the peculiarities thus acquired become permanent,—at least to such a degree as to require an equally long series of causes and effects to restore the original character.

It is so with other animals. The dog, for instance, is universally admitted to form one species, yet how great the variety of breeds produced by the influence of climate, and other circumstances. One breed is permanently and unchangeably acute in the sense of smell,—another is noted for speed of foot. One is sagacious—another strong,—and a third ferocious. We say these peculiarities are permanent and unchangeable—and they are so, at least to such a degree that it would require a very long course of years, and very special training, the results of which should accumulate through many generations, to reverse them.

Now it may be so with men. We do not mean to discuss here the question of the equality of the negro, or any other race to the rest of mankind in intellectual power. We only say that their present equality does not *necessarily follow* from their common origin. The lapse

of ages has produced *physical* peculiarities, which are now fixed. The flattened head, — the thick lip, — the diminutive, or the gigantic stature, — the red, or black, or copper colored skin, have become indelible marks of the various divisions of the human family. In the same manner, the gayety of the Frenchman, the gravity of the Spaniard, the mildness of the Hindoo, and the general intellectual superiority, or inferiority of the Mongolian or Caucasian, or negro race, may have become fixed characteristics, which circumstances now can but slowly change.

That there should be thus, in the course of ages, a marked and permanent difference among the races of men, springing originally from the same stock, is rendered not improbable from another circumstance, viz. the difference which exists between different *families of the same nation*. In this case, the origin is confessedly the same, and yet how great a difference in intellectual or physical power is sometimes observed. One family will be distinguished in all its members for uncommon acuteness of intellectual powers. Another will be noted for the reverse, so that with the best advantages they will scarcely rise above mediocrity; and these peculiarities will sometimes remain from generation to generation, until they are gradually lost. In the same manner the great divisions of the whole human family may come to differ in intellectual power, so that equal advantages will not bring equal rank, and many generations may be necessary to restore the equilibrium.

¶ The question then of the intellectual equality of the various races of mankind, — we mean the equality in respect to the *native* powers of the individuals, as they now successively come upon the stage, — is to be settled by an appeal to facts. Do these various races under the same circumstances, attain to the same successful cultivation of the arts of life? When circumstances are favorable, do they make equal progress? — and when war, or pestilence, or famine, or any other great calamity, involves them in ruin, and throws them back to the state of nature, do they, with equal rapidity, and certainty, recover from the shock and rise to refine-

ment and prosperity again ? To discuss and decide these questions, a very full review of the history of the human race would be necessary, and however it may be decided, we must at all events acquiesce in the decision of scripture, that '*God has made of one blood all the nations of the earth.*'

AGENTS

FOR THE

SCIENTIFIC TRACTS.

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Portland, *Samuel Colman.*
Hallowell, *C. Spaulding.*
Augusta, *P. A. Brinsmade.*
Bangor, *B. Nourse.*
Belfast, *N. P. Hawes.*
Eastport, { *H. S. Favor,*
 { *B. Folsom.*
Norway, *Asa Barton.*

NEW HAMPSHIRE.

Dover, { *Eli French,*
 { *S. C. Stevens.*
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Portsmouth, *John W. Foster.*

VERMONT.

Burlington, *C. Goodrich.*
Brattleboro', *Geo. H. Peck.*
Windsor, *Simeon Ide.*
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SCIENTIFIC TRACTS.

NUMBER XX.

ELECTRICITY.

INTRODUCTORY REMARKS.

MANY centuries ago it was noticed that a certain substance called amber had a very peculiar property. When it was rubbed upon dry cloth or flannel, it had the power of attracting light substances. Feathers, down, and particles of dust would adhere to it, and if removed, they were drawn forcibly to it again. The Greeks first observed this phenomenon. The Greek name for amber was *Elektron*. Hence they expressed this attractive power, by the term *Electricity*, or rather by a term from which the English word electricity has, by a slight change of form, been derived.

Amber is not a very common substance in our country, but the above experiment may in substance be tried by any one, with a peice of *resin* or *gum* of almost any kind, for almost all resinous substances possess this power. Spread upon a table a little lint, or a few fibres of cotton, or the light downy part of a feather; then take a piece of resin having a smooth surface, and after warming and drying it, rub it briskly upon a piece of woollen cloth or dry flannel. Upon bringing it, then, near the light substances before mentioned, they will be found to be attracted towards it, and will adhere to it a long time.

The reason why *light* substances are used in this experiment, is not that they are more strongly attracted than others, but because they may more easily be moved by the attraction, and consequently the effect will be more manifest. The resin will attract a steel needle as strong-

ly as it will a feathery fibre as large as the needle. But this attractive force will be sufficient to lift and to sustain the feather, while it will not move the needle, on account of its great weight. If, however, we suspend the needle in such a manner that it can be easily moved, the attraction will be as manifest as in the case of any substance whatever. This may be done by means of a thread. The needle suspended by it will swing like a pendulum, and if the resin after being rubbed is brought near it, the needle will be found to move sensibly towards it.

This single experiment with the amber stood for a long time alone. It was not in these days, as it is now, the custom to scrutinize with eager curiosity such phenomena, and to trace them back to their causes and connexions. In modern times, however, this subject has been very extensively examined. Many facts of a very interesting character have been ascertained. Many other phenomena have been observed and traced to the same cause with the attraction of the amber. These facts have been classified and arranged ; the manner in which the cause of them operates in various circumstances, has been brought to view, and thus a most important and valuable science has arisen, which we call in memory of the substance, whose properties first attracted attention to the subject, the *Science of Electricity*.

NATURE OF ELECTRICITY.

The *cause* of the various phenomena hereafter to be described, is called *Electricity*. It is generally considered a *fluid*, which pervades all bodies in nature. If it is a fluid it must be extremely different in its nature from all other fluids. There is much difficulty in regard to the nature of three substances, whose effects are well known, *Light*, *Heat*, and *Electricity*. If it were possible to describe the *effects* of these agents, — the *phenomena caused by them*, without adopting any theory in regard to *their intrinsic nature*, we should prefer to do so. But this is not possible. For convenience then of language we call electricity a *fluid*, without meaning to ex-

press any opinion in regard to its substance. All that is properly known of it, is *its effects*, and such of its characteristics as may be fairly and logically inferred from its effects. These last are however very few. The principal object therefore of the following tract, is to present in a systematic form, the prominent facts, and classes of facts, which it is common to refer to this cause. We must first however say something of the theory.

A theory in any science may be of great advantage, even though there be not positive evidence of its truth. Sometimes it is only a hypothesis, adopted simply for the purpose of *arranging* and *systematizing* the facts observed. In such cases it is of great service in reducing to order what would otherwise be a mass of inextricable confusion.

Some theory, for this latter purpose, is necessary for the science of electricity. If we attempt to look at the facts themselves individually, without any theory, we shall have before us a confused and heterogeneous mass, which it is almost impossible to remember, or to recall when occasion requires. Consequently theories have been devised for the purpose of grouping, and arranging the facts, and assisting the recollection of them.

There are two prominent theories which have been employed for this purpose in electricity. The one which is now almost universally received among philosophers, we shall proceed to explain. We do not offer it as positively true or as proved by experiment. Subsequent discoveries may entirely destroy it, but an acquaintance with it is absolutely necessary to the general reader. For in the first place, it is impossible for us to describe the facts in this science without using the language of theory;—and in the second place, this theory is now so universally received, that no book on electricity would be intelligible to a reader without a knowledge of its principles.

The hypothesis is, that there is pervading all substances a subtle and highly elastic fluid, which is however itself entirely void of any sensible weight. This fluid is supposed to be capable of moving over the surfaces of different bodies,—in some cases with greater, and in

others with less degrees of rapidity. In some substances called *conductors* it moves without any apparent obstruction, but, in glass, resin and all bodies called *non-conductors*, it moves with great difficulty. This fluid exists in two distinct forms called *resinous* and *vitreous*. Each of these, when separate, have the general properties enumerated above; but in relation to each other there is a complete contrariety in their natures, so that when combined together their powers are completely balanced and neutralized, and all visible action ceases. This state of union, is the *natural state* of electricity in all bodies.

1. *Theory of the excitation of the electric fluid.* By various causes this state of union may be disturbed. When this is done, the powers before latent are called forth by the separation of the fluids. The vitreous passes in one direction and the resinous in the opposite, and each existing thus in a separate state, produces its peculiar effects. Thus, when glass is rubbed with silk, a portion of the electricity of these bodies is decomposed. The vitreous electricity goes to the glass; the resinous to the silk; and then each can produce visible effects. In the same manner when sealing wax is rubbed with flannel a similar separation takes place. The resinous electricity however enters the sealing wax and the vitreous the flannel.

2. *Theory of electric attraction and repulsion.* Each of these fluids are supposed to be elastic, and consequently their particles repel each other. From very exact experiments it has been ascertained, that the force of this repulsion is inversely, as the square of the distance; and this repulsion is not interrupted by the intervention of any other body.

Although each fluid repels itself, each exerts a strong attraction for the opposite species, and this attraction increases with the diminution of distance, and in the same ratio as the repulsion mentioned above; — that is, in the inverse ratio of the square of the distance. This force of attraction between the *opposite* electricities, like the repulsion between the particles of the same kind, is not affected by interposing any foreign body between them. For example, if two pith balls resinously electrified, have

a plate of glass or of iron placed between them, they will still repel each other, as if there was no intervening object. If one is resinously, and the other vitreously electrified, they will attract each other notwithstanding the intervention of the plate.

3. *Theory of the discharge of the electric fluids.* Let us suppose two brass balls to be charged, one with the vitreous, and the other with resinous electricity. Let both of them be suspended by silken threads, at the distance of several inches from each other. The silken thread is a non-conductor, the air around the balls is a non-conductor, and the vitreous electricity of the one ball, and the resinous electricity of the other, though they have a strong tendency to come together, into their original union, yet they cannot pass through the intervening space, for both balls are *surrounded by non-conductors*; or in the technical language, they are insulated. If now, a *wire* is brought into contact with both the balls, a connexion will be formed, for the wire being a conductor, the two fluids can pass across it and thus become united, and diffused in their natural state of union, over both the balls.

4. *Theory of induction of electricity.* If a ball vitreously electrified and suspended by a silken thread, so as to be *insulated*, that is, surrounded by non-conductors, is brought near to the extremity of a brass rod, in its natural state, but suspended by a silken thread, the vitreous electricity of the ball will repel the vitreous electricity which is in the *nearest* extremity of the rod. This vitreous electricity will pass consequently to the other extremity. The ball, however, besides repelling the *vitreous* electricity will attract the *resinous* electricity of the rod to the end nearest itself; for it was stated above, that vitreous electricity attracts the resinous, as well as repels the vitreous. The rod then, through the influence of the ball, will have its resinous electricity collected at the extremity nearest the ball, and its vitreous electricity driven back to the extremity farthest from it. Thus the ball, by its presence merely, will electrify the rod, throwing the two extremities into opposite states. This corresponds evidently with the theory, and is always found to

take place in experiment. Universally, whenever an electric body is brought near others in their natural state, it produces contrary electricity in those parts which are nearest to the electrified body. This is called *induction of electricity*.

These may be considered as the fundamental principles of the theory. It was originally proposed by Du Faye, a French philosopher. Franklin proposed another, in which he supposed only one kind of electricity. When bodies had an excess of this, they were said to be *positively* electrified;—when there was a deficiency, *negatively*. The *positive* electricity of Franklin corresponds to the *vitreous* of Du Faye, and the *negative* to the *resinous*. The theory of two fluids is now almost universally received. We shall accordingly adopt its phraseology in this treatise, and proceed to describe the facts which constitutes this science, under the following heads.

- I. *Effects produced by electricity in its natural state.*
- II. *Means of accumulating the electrical power.*
- III. *Effects produced by electricity when accumulated.*
- IV. *Effects produced by electricity when in motion.*

I. EFFECTS PRODUCED BY ELECTRICITY IN ITS NATURAL STATE.

We know, unfortunately, very little in regard to this branch of our subject. The universal diffusion of this agent, leads us to suppose that the Author of Nature, who does nothing in vain, accomplishes some important ends by it, in its ordinary and natural operation. Whatever these ends may be, philosophers have almost entirely failed to discover them. Various experiments have been performed with a view to develope some unseen power exerted by electricity, in the process of vegetation,—in muscular motion,—in the phenomena of crystallization,—and in the ordinary fluctuations of wind and weather. But these attempts have been attended with very partial success. Some things, indeed, of a very interesting character have been brought to light, and which, in a more full treatise than this, would de-

serve special mention. These are however few. Nearly all the phenomena which have attracted attention, are those which result from *disturbances*, produced by nature or art, in the equilibrium which electricity ordinarily assumes. Sometimes this equilibrium is disturbed, i. e. an unusual quantity of electricity is collected, or a body is deprived of its natural share by the electrical machine, and sometimes this effect is produced by the great processes of nature. We are thus presented with the various phenomena of the laboratory, or the dreadful explosions, which take place in clouds and storms. We proceed, therefore, to describe the modes by which electricity is accumulated.

II. MEANS OF ACCUMULATING THE ELECTRICAL POWER.

1. By *condensation of moisture*. If water is poured upon burning coals, a great quantity of vapor is produced, which, rising into the cold air, is immediately condensed, forming a white cloud, which ascends from the blackened coals. If now a wire is exposed to this vapor, which wire is connected with a delicate electrometer, i. e. an instrument hereafter to be described, by which minute quantities of electricity are made sensible, it will be found that electricity is accumulated in the vapor. This method is never employed however for practical purposes. It is interesting chiefly from its being the mode by which the fluid is generally accumulated in nature. The clouds are masses of condensed vapor. When they are suddenly formed, they become rapidly charged with the fluid, which darts to other clouds and to the ground, and constitutes the lightning.*

It is a common though very absurd notion, that the lightning is caused by sulphurous vapors which collect in the air, and by some unaccountable means, take fire and explode. There is no way by which such vapors can be formed;—if they were formed they would be diffused and mixed with the atmosphere, and rendered no longer inflammable;—and even if we suppose them

* See Scientific Tract on the Weather.

to be formed, and kept together, it would be very singular that they should take fire only in the midst of a drenching shower.

2. By *friction*. It was by friction that electricity was originally discovered, in the experiment with the amber already described. It has since been ascertained that many other substances, when first rubbed, will exhibit the same effects. For example, if a tube of glass be rubbed with a silk handkerchief, the electricities will be separated; — the resinous will accumulate in the handkerchief, and the vitreous in the glass. The cause of this change is not known, the fact only has been observed. If after the friction of the glass with the silk, the two are separately examined, both will be found electrified, but they will be in opposite states. If, however, we take a rod of sealing wax, instead of glass, and rub it with *flannel*, the effect will be reversed. That is, the *resinous* electricity will accumulate in the sealing wax, and the vitreous in the flannel. Glass by friction with almost all substances becomes *vitreously*, or *positively* electrified. Resins by friction with almost all substances become *resinously* or *negatively* electrified. Those substances called *conductors* of electricity will not become electrified by friction at all. Nearly if not quite all other bodies may. The reason why conductors cannot be electrified by friction seems to be that, on account of the ease with which the fluid passes over them, no separation of the two electricities can be effected. Those substances which can be electrified by friction are called *electrics*. The following is a list of the most important of them: — Glass, Precious Stones, Amber, Sulphur, Shell-lac, Resinous and Bituminous substances, Silk, Wax, Cotton, and dry animal substances, as Feathers, Wool, Hair, &c, Paper, Dry Sugar, Air and Gases.

This method of accumulating electricity, viz. by friction, is the most commonly resorted to, for experiments. The apparatus is called *the electrical machine*. It consists of glass, either in the form of a cylinder or plate, mounted in such a manner as to be turned rapidly, by a crank. A rubber, made of silk is pressed against the glass while in motion, and thus the vitreous electricity is

accumulated upon the glass, and the resinous upon the rubber. It is plain, that the form of the glass is not material, excepting that one form may more easily be mounted than another. The most common form is a cylinder or a jar. Any common open mouthed jar will answer for this purpose. Sometimes plate glass is used. The advantage of this is that a rubber may be applied to each side of the glass, which increases the effect. A plate machine is however much more liable to be broken, and is consequently less frequently used. The axis upon which the glass turns may rest upon wooden supports. It is desirable however that the rubber should be supported by a glass pillar, for reasons which will hereafter be explained. The forms which the electrical machine has assumed are very various. Different artists have arranged the parts to suit their own fancy, or the particular purpose for which each machine is intended. Almost all electrical machines, however, consist essentially of glass cylinders or plates, put into rapid motions by means of a crank, so that a great amount of friction may be secured with as little labor as possible to the operator. This is all that is *essential*, and by understanding this general principle, the reader can, by inspection, clearly comprehend the details of any particular machine which he may have the opportunity of examining.

The electricity thus accumulated upon the glass of the electric machine is received usually upon a metallic cylinder, which is a sort of reservoir, where the fluid is preserved for use. From this cylinder which is called the *prime conductor*, there proceed a number of sharp *metallic points*, by which the electricity passes off from the glass cylinder to the conductor. The reason why these points are used will be hereafter explained. The prime conductor may be made of any substance, provided that it has an *external surface of metal*. Sometimes it is made of *wood*, and coated with sheet lead or tin foil. Sometimes it is of tin or brass plate, and hollow. The writer of this tract once constructed a large one, five feet long, and eight or ten inches in diameter, of thin pine boards, put together like the staves of a barrel, — and coated with sheet lead. The prime conductor may

be made of any size or form, or of any substance which is a conductor of electricity. All that is essential is that it should be insulated, that is, supported and surrounded by *non-conductors*, so that the electricity which it receives may be retained. A conductor of immense size was once constructed of common military drums, coated with tinfoil, and placed one upon another, forming a lofty column, which was supported at the base by a cake of beeswax which cut off all electrical communication with the ground.

The human body may be used as a prime conductor. In order to insulate it, an instrument is used called an *Insulating Stool*. It consists simply of a stool with glass feet. These feet or legs may be common phials, with the neck cemented into the board, which forms the upper part of the stool. A board supported upon four common tumblers, or a cake of beeswax will answer the purpose equally well. The human body thus insulated may be charged with electricity, and from it the fluid will pass in sparks to the surrounding bodies. Young persons, who amuse themselves with electrical machines, find an inexhaustible source of pleasure from these experiments upon each other.

Besides the prime conductor, there is another sort of reservoir for the electric fluid when it is developed by the electric machine, which is far more efficient. It is called the *Leyden Jar*. The reader will recollect that on the subject of the theory of electricity, it was stated that any body, when electrified, and brought near to other bodies, would cause them to assume a contrary electrical state. Consequently, if two prime conductors, one positively electrified, and the other in its natural state, are brought within the influence of each other, the last mentioned will become negatively electrified, and upon forming a connexion between the two they will both be suddenly discharged. The effect will be increased in proportion to the nearness of the two conductors. If however there is nothing but air between them, they cannot be brought very near or they will discharge themselves through the air. To obviate this difficulty, a thin glass plate may be interposed, and in order

that the form of the two conductors may be such, as to bring every part of each under their mutual influence, simple sheets of tin foil are used, pasted, one on each side of the plate of glass. Now if one of these sides is connected with the electrical machine, and the other with the ground, both will become, on principles already described, highly charged;—the one side by direct communication and the other by *induction*, as explained on page 477. The two sides will however be charged with opposite electricities.

A glass plate, coated in this way, on the two sides, would not be a very convenient apparatus. The same arrangement is however effected by means of a jar, which is coated within and without. From the inside there arises a wire with a knob upon the top. This knob is brought into contact, when the machine is in operation, with the prime conductor, and thus the *inside* of the jar is positively electrified. By the influence of the electricity thus conveyed into the inside of the *jar*, acting *through the glass*, the outside is thrown into the opposite state, and by forming a communication between the two, a discharge results, which produces far more powerful effects than the prime conductor.

It ought to be noticed, however, that the form of the jar, and the manner in which it is coated, are of no consequence. All that is essential is that there should be *two metallic surfaces, separated by glass*. Sometimes the jar is filled with shot. Sometimes coated with tin-foil,—sometimes with brass or iron filings, made to adhere by gum water. The experiment will even succeed with a tumbler, half filled with water, for the inside coating, and covered on the outside, as high as the surface of the water, with wet paper. In all cases the upper part of the glass, which is not covered with the coating, should be kept perfectly dry and clean, lest by the moisture accumulated there, there should be an accidental communication formed between the inside and outside of the jar.

‘It is hardly necessary to observe, that every species of electrical machine will naturally require some particular precaution; but the following directions are more or less

applicable to all kinds of machines furnished with a glass electric.

‘Moisture and dust, but particularly the former, being detrimental to the power of an electrical machine, it becomes necessary to guard from both as much as may be practicable; hence, when not actually in use, the electrical machine should be kept in a dry and clean place, and at least the glass part of it should not be suffered to remain dirty and soiled. If the machine has been long neglected, the operator in order to render it ready for use, must in the first place remove the rubber; he must then place the machine at a moderate distance from the fire; so as to render every part of it very dry, but not too warm. This done, and the dust removed, the glass part of the machine must be repeatedly rubbed with a clean and warm handkerchief or towel; the rubber, likewise must be cleaned, removing all the old amalgam that may have adhered to it. The glass cylinder or plate, in its rotation frequently contracts some dark spots or concretions upon its surface, which tend to diminish its power. These spots which adhere pretty fast to the glass, may be removed by applying a finger’s nail to each spot, or by rubbing them off with a piece of coarse canvas. Previously to the replacing of the rubber, the following operation generally contributes to increase the excitation. It consists in touching the cylinder with the bottom of a tallow candle in streaks parallel to the axis of the cylinder, then rub the cylinder again with a dry and warm linen cloth; taking care that this cloth be not very old, for in that case it is apt to leave filaments about the glass, and about the rest of machine. This done, the rubber is fixed in its place, and its support is adjusted, so that the rubber may bear upon the glass with a proper degree of pressure. Formerly the amalgam, which greatly increases the power of excitation, was spread upon the rubber, before the rubber was put in its place; but experience has shown, that it is much better to fix the rubber clean in its place, and then to apply the amalgam upon a piece of leather to the surface of the cylinder while this is revolving in its usual directions; for by this means the revolution of the cylin-

der or plate, will carry away from the leather a sufficient quantity of amalgam, and will deposit it upon the rubber. The leather with the amalgam needs not to be kept in contact with the glass longer than while the cylinder makes eight or ten revolutions; moving, at the same time the piece of leather with the amalgam from one end of the cylinder to the other. Now if the cylinder be turned, and if the hand or the end of the fingers be presented to it, a crackling noise, which is accompanied with numerous brushes in a dark room, indicates that the cylinder is in good action; and the prime conductor being situated in its proper place, you may proceed to perform the experiments. During the performance, the electrified part of the machine is apt to attract dust from all quarters, to obviate which the room ought to be previously swept and dusted, and likewise the operator ought to have a clean cloth at hand to wipe off all particles of dust and filaments, which in spite of all his precautions will frequently run to the cylinder, to the conductor, &c.

‘The amalgam remains to be described. Mr Canton, as far as we are informed, first applied the amalgam of tin and mercury to the rubber of an electrical machine, which was undoubtedly a capital improvement; for by this means an electrical machine will have its power more than quadrupled. The tin amalgam is easily made, for if you triturate tin foil and mercury, (in the proportion of one of tin to two parts of mercury) in a mortar, or even in the palm of your hand, the amalgam will be formed in a minute or two.

‘The amalgam of mercury and any metallic substance that may be amalgamed by it, contributes to increase the electric power of glass, but some are more efficacious than others. *Mosaic gold* has also been found efficacious for the purpose of excitation. The zinc amalgam, however, which was first recommended by Dr Higgins, has upon the whole been found the most efficacious. This amalgam, which consists of one part of zinc with four or five parts of mercury, is, according to Mr Cavallo, prepared in the following manner. ‘Let the quicksilver,’ he says, ‘be heated to about the degree of boiling water,

and let the zinc be melted in a crucible or iron ladle. Pour the heated quicksilver into a wooden box, and immediately after pour the melted zinc in it. Then shut up the box and shake it for about half a minute. After this you must wait until the amalgam is quite cool, or nearly so, and then you may mix some grease with it by trituration. If the melted zinc be poured into the quicksilver when cold, a very small portion of the former will be amalgamed, the rest remaining in lumps of different sizes.'

The following drawing and description of a simple Electrical Machine and conductor, is from Cavallo.

The figure represents an electrical machine of the simplest sort. *G E F*, is a strong board, which supports all the parts of this machine, and which may be fastened to a strong table by means of one or more iron or brass clamps, as at *Q*. The glass cylinder *A B*, quite clean and dry in its inside, is about ten inches in diameter, and is furnish-

ed with two caps either of wood or brass, into which its two short necks are firmly cemented.* Each of these caps has a pin, or projection, or pivot, which turns in a hole through the wooden pieces *A* and *B*, which are cemented on the top of glass pillars, (or pillars of baked wood,) *B E* and *A G*, which are firmly fixed to the bottom board *G E F*. One of the above mentioned projections passes quite through the wooden piece, as at *A*, and has a square termination, to which the winch *A D* is applied and secured on by means of a screw-nut. Then by applying the hand at *D*, the operator may turn the cylinder, &c. Sometimes the part *A C*, of the

* The best cement for this purpose is made by melting and incorporating together five parts of resin, four of beeswax and two parts of powdered red ochre.

winch is made of glass, in order the more effectually to prevent the escape of the electric fluid from the cylinder. This is not, however necessary, nor is it even necessary to have the pillars of glass. *IR*, is the rubber, and *IRK*, is the silken floss. This cushion or rubber is fastened to a spring, which proceeds from a socket cemented on the top of the glass pillars *S*. The lower part of this pillar is fixed into a small board which slides upon the bottom board of the machine, by means of a screw-nut, and may be fixed more or less forward in order that the rubber may press more or less upon the cylinder. *NF* is a glass pillar which is fixed in the bottom board, and supports the prime conductor *ML*, of hollow brass or tin plates, which has the collector or pointed wires at *L*, and knobbed wire at *M*. From this brass knob *O*, a larger spark may be drawn than from any other part of the conductor. But this knobbed wire is only screwed into the conductor, and may be easily removed from it.

These three articles of electrical apparatus, the *Electrical Machine*, the *Prime Conductor*, and the *Leyden Jar*, are the most important instruments used for exciting and accumulating the electrical power. We come now to consider our third division.

III. EFFECTS PRODUCED BY ELECTRICITY WHEN ACCUMULATED.

1. *Distribution of electricity over the surfaces of bodies.*

It was early observed that the electric fluid resides *on the surface*, not *within the substance* of the electrified body, but the manner in which it distributes itself over the surface was left, strange as it may appear, to be discovered by the application of purely mathematical reasoning. The existence of the fluid, and the repulsion between its particles, were the data in this investigation, and from these, the manner in which it must distribute itself over bodies of every possible variety of form, may be precisely ascertained. In order to determine whether these results of theory should correspond with observed fact, M. Coulomb made use of his celebrated *torsion balance*, the principles of whose construction have been

already described in the Tract on Gravitation. By means of this, very minute forces could be accurately measured. Coulomb cut out a small disc or circle of gilt paper, which he attached to a silk thread. This he called the *proof plane*, and by applying this successively to the various parts of an electrified body, and bringing it to his balance, the degree to which the various parts were charged, were very accurately ascertained. The results of these experiments were found to correspond very exactly with the theory. Some of the general principles in regard to the manner in which electricity diffuses itself over the surfaces of bodies, thus doubly proved, are as follows.

(a) If a *spherical* body be charged with electricity, vitreous or resinous, the whole fluid is, in consequence of the repulsion of its own particles, accumulated in a thin, *uniform* stratum at the surface.

(b) If the body, instead of being spherical is *elongated*, then there will be a greater charge toward the *extremities*, than near the middle.

(c) If the elongation of the body is carried as far as possible, i. e. if it assumes a *pointed* form, the accumulation of the fluid at the extremities, will be increased to a very high degree, and the electricity will pass off in a rapid stream.

(d) The electricity of a charged body, resides *at the surface*. Coulomb ascertained this by experiment in this way. He caused little holes or pits to be bored in a brass ball, and then after having charged it, he let down his *proof plane* to the bottom. On withdrawing it, and applying it to his balance it gave no signs of electricity.

2. Attraction and Repulsion.

It has been before stated, in the brief notice of the Theory of Electricity, that a repulsion always exists between bodies similarly electrified, and an attraction between those which are in opposite states. It will also be remembered that, by the process called *induction*, which has been described on a previous page, whenever a body electrified in either way, is brought into the vicinity of other bodies *its mere presence electrifies* them. An electrified body will

consequently always be surrounded by other electrified bodies. I bring a brass ball highly charged with electricity, and suspended by a silk string or held by a glass handle, so as to be insulated, over a table containing upon it small pieces of paper. By *induction* the ball electrifies the paper in a manner contrary to itself. The ball and the paper are consequently in opposite electrical states, and will therefore attract each other. The papers will fly up to the ball. This experiment in substance, may be tried by the reader. Rub with a hot silk handkerchief, a dry and clean tumbler; it will become electrified and will attract to it the bits of paper, as well as if a brass ball were used. Suppose a thunder cloud highly charged with vitreous electricity is passing. Its influence is to electrify resinously the region over which it moves, and it will be attracted by it, and drawn down nearer the earth. And universally, an electrified body produces an opposite electrical state in the neighboring bodies, or parts of bodies, and then attracts them.

On the other hand if two bodies *similarly* electrified are brought near each other, they repel. If, for example, two pith balls, both electrified positively, are suspended by threads near each other, they will recede, and hang in diverging lines.

This principle of repulsion between similar electricities, and attraction between those of an opposite character, is the foundation of many amusing experiments, some of which we shall proceed to describe.

1. *The pith balls.* If one small pith or cork ball, is suspended by a thread, and another, electrified, is brought near to it, they will attract each other. If the stationary ball is previously electrified in a manner opposite to the other, they will attract more strongly; if in a similar manner, they will repel.

2. *The Electrometer.* Electrometers are instruments designed to measure electricity, or rather to indicate its intensity. They are of several kinds. Two pith balls suspended at the end of a rod of glass, diverge when brought near any electrified body, for they become similarly electrified, and repel each other. Sometimes a pith

ball *a* is fastened at one extremity of a light and slender rod *c a*, moving on the centre *c*. The part *b* is inserted into the prime conductor. When the conductor is charged, the stem *c b* and the ball *a* become similarly electrified and of course repel each other. The ball accordingly rises up the quadrant *e a* to a height which depends upon the intensity of the charge. This is called the

Quadrant Electrometer.

There is a *Silver Leaf Electrometer*, extremely delicate in its structure and operations. Two slender strips of silver or gold leaf are suspended from the same point. The electricity causes them to diverge. Various other instruments for the purpose of indicating the presence of electricity, have been contrived, but they are all on the principle of the divergence of light bodies freely suspended, and similarly electrified.

3. *The divergent hair*. If an individual whose hair is loose and flexible, stands upon the insulating stool and is electrified, the hairs of the head, each being repelled by the others, stand out in all directions, and present a very grotesque appearance. Sometimes a little image is made with hair of a peculiarly dry and flexible character, to be attached to the prime conductor.

4. *The electrical snow storm*. A hollow metallic cup is placed upon the prime conductor and filled with light shavings of pith, or small pieces of paper, or any other similar substance. When the conductor is electrified these become mutually repulsive, and fly off in every direction, producing what the electricians call an electrical snow storm.

5. *The electrical jet*. A little vessel with a hole in its side, so small that the water oozes through in drops, is hung upon the prime conductor. When the apparatus is charged, the mutual repulsion of the particles causes the water to fly out in a stream.

6. *The thread of sealing wax*. Attach a small piece of sealing-wax to the extremity of a wire, and warm it so as to render it ready to drop; and at the same time

let the electrical machine be worked ; then stop the motion of the machine, and instantly bring the hot sealing-wax within four or five inches of the prime conductor, moving it about in a winding direction, and you will find that the sealing-wax throws several exceedingly fine threads to the prime conductor, which appear like red wool. This experiment answers best where the conductor is covered with varnish.

Mr Adams describes this experiment in the following manner. 'Stick,' he says, 'a piece of sealing-wax on the conductor in such a manner, as it may easily be set on fire by a taper. While it is flaming, turn the cylinder, the wax will become pointed, and shoot out an almost invisible thread into the air, to the length of a yard and more. If the filaments that are thrown out by the wax are received on a sheet of paper, the paper will be covered with them in a very curious manner, and the particles of the wax will be so far subdivided as to resemble fine cotton. To fasten the piece of wax conveniently to the conductor, stick it first on a small piece of paper, then twist the end of the paper so as to fit one of the holes which are made in the prime conductor ; when it is thus placed it may easily be fired by a taper.'

7. *The dancing images.* A flat circular piece of copper is suspended in a horizontal position from the prime conductor. At the distance of a few inches from it, another similar piece is laid upon the table or upon something connected with the table. Upon this last metallic plate, the experimenter lays a few paper images, generally made of a grotesque form, and upon charging the prime conductor and of course the upper metallic plate, these images are attracted to it. Upon coming in contact they become similarly electrified, and are consequently immediately repelled. They fall back to the lower plate, where they part with their electricity, and are immediately attracted again, and thus by an alternate attraction and repulsion, they dance from one to the other with no little agility.

8. *The dancing balls.* In this case the inside of a tumbler is charged by bringing the parts successively into contact with a brass ball connected with the prime con-

ductor. This tumbler is now inverted over a number of pith balls lying upon the table, and the balls by an alternate attraction and repulsion, similar to that explained at length under the head of dancing images, leap up and down until they have conveyed away all the electricity from the glass to the table and thus to the earth.

9. *The electrical spider.* Two Leyden jars are electrified with opposite electricities, and a little image of an insect, — the form of the spider is generally chosen, — is suspended between them. The spider is attracted to one, then repelled, because at the moment of contact, it becomes similarly electrified; it is then immediately attracted to the other, — to touch it, and to fly off again at the instant of contact. This flying from one to the other continues until the jars are discharged.

10. *The electrical bells.* An apparatus is made by which two bells hanging side by side, are connected, the one with the prime conductor, and the other with the earth, a little brass ball is suspended between them which, precisely on the principle above described, swings from one to the other, giving each a slight stroke sufficient to emit a very distinct sound. As the clapper flies across with great rapidity, and in ordinary cases there are three bells, two of which are connected with the conductor, the apparatus keeps up a very merry ringing, sometimes for half an hour.

It is said that Franklin had an apparatus of this kind attached to his lightning rod by the ringing of which, he was notified of the approach of thunder.

11. *Electrical powders.* Perhaps the most beautiful of all the experiments illustrating electrical attraction and repulsion, are those in which various powders are attracted to electrified surfaces. One of the simplest modes by which the experiment can be performed is as follows: Pour upon a small board with raised edges, a quantity of resin. When it is cooled, it forms a smooth and level surface. Touch this surface in several points with the knob of a jar electrified vitreously or positively, and in several other points with the knob when it is electrified resinously or negatively. The knobs will communicate there respective electricities to a little region around the

points of contact. Mix now some red lead and sulphur as intimately as possible, and by means of a bellows or some similar contrivance, project them thus mixed through the air. As they pass through the air, the red lead by the friction becomes electrified vitreously, and accordingly it will be attracted towards the *resinous* spots. The sulphur electrifies itself resinously and will accordingly be drawn towards the *vitreous* spots. Thus the two powders will be entirely separated, and will arrange themselves in beautiful figures upon the plate. They will gather around the vitreous spots in long and beautiful ramifications, extending in every direction from the point touched, and upon those electrified resinously the powder will gather in a circle uniformly covered, but not very distinctly defined.

‘These powders may be sifted over the electrified body from a common sieve; they may be tied up in linen rags, and shaken out of them; they may be projected by means of a brush; also by means of a pair of bellows. But a more commodious method is as follows: Fix a tube of wood, or glass, or metal, to the neck of a small bottle of India rubber; put the powders to be projected into this bottle, and then tie a double piece of flannel over the aperture of the tube. If this bottle, so prepared, be held in the hand, and be squeezed by alternately opening and shutting the hand, the powders will be projected in a fine diffused manner.’

‘These experiments with the powders may be almost endlessly varied. The following are some of the most usual forms.

(a) ‘Take a pane of glass, clean and dry, hold it suspended by one corner, or lay it flat upon a table, and draw over the surface of it the knob of a Leyden phial, moderately charged with positive electricity in its inside; then lift up the glass, if laid upon the table, and holding it suspended, project upon it a mixed powder, consisting of powdered dragon’s blood and gum arabic in equal parts. The two powders will be separated upon the glass; the red powder of dragon’s blood falling on certain places, so as altogether to form an oblong, radiated track, consisting of two colors intermixed in a thousand

odd ways. If, instead of drawing the knob of the jar over the surface of the glass, we only touch the surface of it here and there with the knob of the jar, and then project the mixed powders as before; separate star-like figures will be formed about those points. The stars, however, are more defined where a single powder is projected. Their rays or ramifications sometimes are few and strong; at other times they are numerous and slender; and frequently they do not go quite round the points which had been touched with the knob of the jar.

(b) 'Repeat the preceding experiment with this variation only; viz. that now the Leyden phial be charged negatively in the inside, and the appearance of the configurations will be much different from the above described, which was produced by positive electricity. In the present, very few rays or branches will be observed; the powders mostly disposing themselves in roundish spots, and generally it will be found that a central spot of one powder is surrounded by another powder of a different color.

'Instead of dragon's blood and gum arabic, powders of other colors may be projected upon the pane of glass, such as powdered Prussian blue, sulphur, vermilion, resin, &c, and thus the colors of the configurations may be varied.

'These powders adhere to the glass rather slightly, so as not to bear being touched; yet, if a piece of paper be gently laid on the painted side of the glass, without rubbing it, and the edge of the paper be pasted all round the edge of the glass, the figures may be preserved without injury. But a better method is, to lay another pane of glass of the same size upon the former, and to fasten them by pasting a slip of paper all round their edges. If such powders as are used by enamellers be projected upon glass or porcelain, and these be afterward exposed to a proper degree of heat in an enameller's furnace, the configurations will thereby be rendered indelible.

(c) 'Take a piece of common writing paper, hold it very near the fire, so as to render it quite dry and very hot; lay it flat upon a dry marble slab or a very dry table, and in that situation draw over it the knob a charg-

ed!Leyden phial"; then lift up the piece of paper by one corner, and holding it suspended, project upon it the mixed powder of dragon's blood and gum arabic, by means of the elastic gum bottle. The configurations in this case are very beautiful, and may be made in various shapes, such as letters, stars, stripes, &c, by moving the knob of the Leyden phial in the desired direction; but they are of one color; viz. red, for the gum arabic being nearly of the color of the paper, cannot be distinguished upon it. If the paper thus painted be held very near to the fire during a few seconds, the powder of dragon's blood being a resinous substance, will be melted, and will be fastened on the paper; after which the powder of gum arabic may be wiped off with a handkerchief.

'Powders of other colors may be projected upon the paper, after the same manner, but unless they are of a resinous nature, so as to be easily melted by heat, it is very difficult to fasten them to the paper. In these experiments the Leyden phial must not be charged too high nor too low; for in the former case, the figure will be too confused and irregular, and in the latter it will be too faint. In order to form a neat and determinate figure, and to leave the rest of the paper clean, the powders must not be projected perpendicularly to the paper, but the stream must be thrown in a direction parallel to the surface of the paper. It is also necessary to perform these experiments in as expeditious a manner as possible; for, if the paper be suffered to cool too much, or the electricity to dissipate, the desired effect cannot be obtained.'

12. *The flying feather or the electrical shuttlecock.* Take an excited glass tube in one of your hands, and let a small light feather be left in the air, at the distance of about eight or ten inches from the tube. This feather will be immediately attracted by the tube, and will adhere very closely to its surface during a few seconds, and sometimes longer; then, having acquired the same sort of electricity, it will be repelled, and by keeping the tube under it, the feather will continue to float in the air at a considerable distance from the tube. By managing the tube dexterously you may drive the feather to any part of the room at pleasure.

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SCIENTIFIC TRACTS.

NUMBER XXI.

ELECTRICITY.

[Continued.]

IV. — EFFECTS PRODUCED BY ELECTRICITY WHEN IN MOTION.

UNDER this head are to be classed by far the most striking and powerful of the effects of this mysterious agent. When the fluid is in its natural state of diffusion over all bodies, it is, as we have seen, apparently inert and powerless, though we must suppose that it exerts some very important, though secret agency in those silent processes, by which the course of nature is maintained. When the fluid is accumulated, so as to exist in bodies in unnatural quantities, or in an unnatural state, while it is kept in this state, it produces only the gentle effects of attraction and repulsion which have been already described. It will be noticed that in all those experiments on electrical attraction and repulsion, a *motion* of the fluid is alluded to, as a consequence of the arrangement of the apparatus, yet the attraction and repulsion are in all those cases, *anterior* to the motion of the fluid, and consequently are properly to be considered as effects produced by the electricity while at rest. For example, in the case of the electrical spider, the little animal is attracted by the knob of the jar, while the fluid in the knob is at rest;—it approaches in consequence of the attraction, and, on coming into contact, a portion of the electricity passes from the knob and enters the spider. Here is *motion*, and immediately after it, the bo-

dies are placed in a very different state from before. Both are now similarly electrified, and the fluids come again to a state of rest. While in this second state of rest a new effect, viz. repulsion, takes place. Thus it is manifest that though a motion of the electric fluid attends the attraction and repulsion, still these effects are, strictly speaking, produced by the fluid while in a state of rest.

We come, however, now to specify phenomena, which occur during the very instant of motion of the electric fluid.

And here it must be observed that whenever a body is electrified in any way, there must be somewhere in its vicinity, other bodies electrified in an *opposite* way, — and to exactly the same amount. For example, electrify vitreously a ball of brass; i. e. drive off its own resinous electricity, and bring to it an equal amount of vitreous fluid. Now the *resinous* electricity which has been expelled must be existing somewhere in the neighboring bodies, seeking to return, — and the *vitreous* electricity which has been brought to the body, must have left a deficiency in the surrounding bodies, to supply which, the accumulating fluid must be endeavoring to escape, so that whenever a body is electrified by having a surplus of vitreous and a deficiency of resinous fluid, the surrounding bodies will be electrified of course, in the opposite way, that is, by having a deficiency of vitreous and a surplus of resinous electricity. The two surpluses then will have a strong tendency to dart across the intervening space, to supply the two deficiencies, and thus restore the bodies to their natural state.

The same is evidently true if we consider the theory of Franklin, already alluded to, as the more probable hypothesis. In his view of the subject, supposing only one fluid, it is plain that the accumulation of that in the brass ball must be at the expense of the surrounding bodies, so that if the ball is positive, there must be an equal amount of negative electricity in the vicinity, and the tendency of the ball to discharge itself, is merely a tendency of the surplus fluid contained in it, to go back and supply the deficiency in other bodies, which its accumulation in the ball creates.

It must, therefore, be constantly borne in mind, that, to discharge any electrified body, we must *form a communication between it, and the other bodies electrified in an opposite manner*, and we have been thus particular in explaining the cause of this, because ignorance or forgetfulness of this principle, is the source of a vast number of mistakes among young persons, who are attempting electrical experiments.

The surrounding bodies which will be oppositely electrified, as above described, are generally the nearest. Suppose a cloud to be positively electrified, and to be suspended over a particular region of the earth. This region we will imagine to be electrified in an opposite manner. Now let the cloud move over a fresh portion; by its repulsive power it will force off from this new region, the share of electricity which naturally belongs to it, into the vacancy which existed in the region over which it originally stood, and thus, whenever it moves, the opposite electricity of the surrounding bodies will accompany it, and the fluid will always be seeking to dart off from the place of its excess in the cloud to the place of its deficiency in the ground below. And it is only by a communication from one of these to the other, that the cloud can be discharged.

In the case of the prime conductor, the same is true. When it is charged, the experimenter touches it with his finger and it is discharged. His own body and other surrounding bodies connected with his, were in the opposite electrical state, to an extent just sufficient to balance the electricity of the conductor. By touching it then, he forms a communication between the two, the fluid passes, and the equilibrium is restored.

In the Leyden jar, this principle of the necessity of forming a communication between bodies electrified in an opposite manner, in order to discharge them, is still more strikingly exemplified. For here it will be recollected, the outside of the jar is electrified in one way and the inside in another, as was stated in the description of the theory of the jar. The very object of its construction is to bring as nearly as possible together, the surfaces thus brought into opposite states. In order,

therefore, to discharge the jar it is necessary *that a communication should be formed between the inside and outside.* This may be done by the hands of the experimenter. He grasps with one the external coating, and with the other touches the knob, connected with the interior. The communication is thus completely formed, and the fluid will pass until the former equilibrium is restored.

Nothing now is more common than for an individual to approach a charged jar, standing upon a table, and to touch its knob, without forming any communication with the *outside.* Now if the table is dry, it is a non-conductor, and of course though the fluid may pass down to the floor, through the body of the experimenter, it cannot rise through the table to the outside of the jar, except in very small quantities. And the fluid will not leave the inside, till it can, by this means, reach the outside. The jar will consequently be but very slightly discharged. This mistake is made more frequently on account of the fact, that, in order to discharge the *prime conductor*, nothing is necessary but to touch it with *one hand.* For the opposite electricity is not, as in the Leyden jar, situated in a small insulated plate, but is diffused among *all the surrounding bodies*, as the floor, the ground, &c; and the feet of the operator naturally forms a communication with them. So that by simply touching the conductor, a communication is actually formed, — whereas by touching the *knob* only of the jar it is not.

For the purpose of discharging a Leyden jar, or a combination of jars, called a battery, a very useful instrument is employed called a *discharger.* It consists simply of two brass wires, united at one end by a hinge, and having knobs on the other extremities. The arms may be opened to any distance, and from the hinge there proceeds usually a glass handle. One of the knobs is now brought into contact with the outside of the jar, and the other with the inside, and the communication is at once formed.

Having thus shown what are the circumstances in which a motion of the electric fluid takes place, we proceed to explain the nature of this motion.

1. It is instantaneous.

It is very common for a lecturer upon electricity, after explaining fully to his class the fact, that when a communication is formed between the inside and outside of the jar, the fluid passes from one to the other, to request them to form a line by joining hands, and to allow the charge to pass through them all, so as to observe who feels the effect soonest. But when the line is formed, and one extremity is connected with the outside of the jar, and the individual who stands at the other extremity, touches the knob connected with the inside, the start of the whole line is precisely simultaneous. At college this experiment is sometimes tried with some hundreds of students arranged in a long line in the college yard. The one at the extremity most remote from the jar takes hold of a chain which, supported at intervals, returns to the jar, and thus the fluid has to pass through a distance of many hundred feet, but no perceptible difference of time is to be observed.

Another interesting way of exhibiting the instantaneousness of the motion is this. A wire connected, at one end with the outside of the jar, is passed around the room, by fastening it against the wall, so that at last the other end returns near to the table. At any remote part there may be a short interruption, across which the electricity will pass by a visible spark, at the precise instant in which the returning end of the wire is connected with the knob of the jar.

Some English philosophers tried this experiment on a larger scale still. They extended wires, supported by silken strings which they fastened to stakes set in the ground, several miles in length. The discharge was effected through these, and not the slightest difference between the entrance of the fluid at one end of the wire, and its return through the other, could be perceived, though in the interval it must have passed six or eight miles. The motion of electricity may, however, be progressive, — it may consume time, — and yet not be perceptible in so short a distance. Light requires time to pass across any space. This time is very perceptible in

its crossing the earth's orbit, but in going ten miles, it would occupy only the two millionth part of a second, — a period altogether imperceptible to man.

The following extracts from the Article on Electricity contained in the English Library of Useful Knowledge, state some interesting particulars in relation to this part of our subject.

‘By accurate experiments it appears that the force of the electric shock is weakened, that is, its effects are diminished, by employing a conductor of great length for making the discharge. But it is difficult to assign a limit to the number of persons through which even a small charge of electricity may be sent, so that all shall experience the shock; or to the distance along which it may be conveyed by good conductors.

‘At an early period of electrical inquiries, much interest was attached to the determination of these points. The Abbe Nollet passed an electrical shock from a small phial through a hundred and eighty of the French guards in the presence of the king; and at the Carthusian convent in Paris, the monks were formed into a line above a mile in length, by means of iron wires held between them; on the discharge of the jar the sensation was felt at the same moment by all the persons composing this vast circuit. Many experiments were made both by the English and French electricians with a view to ascertain the space which a discharge can be made to traverse, and the velocity with which it is transmitted. Of these the most ingenious and satisfactory were the experiments planned and executed by Dr Watson, with the assistance of the leading members of the Royal Society. A circuit was formed by a wire which extended the whole length of Westminster bridge, at a considerable height above the river; one end of this wire communicated with the outer coating of a charged phial or jar, the other being held by a person on the opposite side of the river, who formed a communication with the water by dipping into it an iron rod held by the other hand. The circuit was completed by another person, who stood near the phial, and who likewise dipped an iron rod into the river with one hand, and was enabled by means of a wire held

in the other, to effect a contact with the knob of the phial. Whenever the discharges took place, the shocks were felt by both persons : thus proving that the electric fluid must have been in motion along the whole line of the circuit, including both the wire above and the river below.

‘In another experiment, made on Shooter’s hill, at a time when the ground was remarkably dry, the electricity was made to perform a circuit of four miles ; being conducted for two miles along wires supported upon baked sticks, and for the remaining distance also of two miles, through the dry ground. As far as could be ascertained, by the most careful observation, the time in which the discharge was transmitted along that immense circuit was perfectly instantaneous : nor has any other trial that has yet been made afforded the least approach to a measurement of the velocity with which electricity moves.

‘On this subject, however, an important distinction should be made between the actual movement of each individual particle of electric fluid, and the transmission of an impulse along a series of such particles, for the one may bear hardly any proportion to the other, just as we find that sound proceeds with a velocity incomparably greater than that of the particles of air which are concerned in its propagation. In like manner the portion of blood, which raises the artery at the wrist, where the pulse is felt, is not the identical portion of blood, which is thrown out from the heart by the contraction of that organ producing that pulsation ; the impulse in all these cases being propagated, like a wave, from one particle to another. There is, therefore, no reason to suppose that the same particles of electric fluid, which enter at one part, have traversed from one end to the other the whole line of conducting substances.’

2. *It always chooses the best conductors which are in its path.*

The distinction between conductors and non-conductors of the electric fluid has been already explained. Some substances allow the passage of the electric fluid with great ease ; — others with greater or less difficulty

The former are called conductors, the latter non-conductors. For example, let a man grasp the outside of the Leyden jar with one hand, and with the other touch the knob with a piece of wood, and only a small portion of the electricity will pass. Let him a moment afterwards touch it with a piece of metal, and he will receive a violent shock. The whole force of the charge will pass suddenly through the metal into his hand.

It is easy to determine whether any substance is or is not a conductor. If it contains anything *metallic* or *moist*, it is, if not, it is a non-conductor. This is a *general*, but not a *universal* rule. Silk and glass are the most commonly used as non-conductors, and brass or iron as conductors.

The tendency of electricity to *choose*, as it were, the best conductors may be shown by a variety of experiments. Charge a Leyden jar, and bring into contact with the outside of it, a wire, and a rod of wood. Let the wire pass around the whole room, and the other extremity be brought near the knob. Let the other end of wood also be brought to the same distance from the knob, and then bring the two ends nearer and nearer until the fluid darts across. *It will invariably strike the wire*, — although it must, by so doing, pass entirely round the room, to reach its destination.

In the same manner, if a variety of objects are laid upon a table, such as chains, money, pieces of glass, &c. Some of whom are conductors and some non-conductors, — and if they are placed almost in contact with each other, and so arranged that there is *one* way, however crooked, by which the electricity may pass across the table through conductors only, — except the *very short* interruptions between them, — the fluid will be sure to find this way. If one end of the table is connected with the inside, and the other with the outside, — the fluid will pass across, choosing with undeviating certainty the conductors, and those alone.

It is so with lightning. It darts from the cloud to the earth, *choosing the best conductors in its way*. If a person stands in such a manner as to be one of such a series of conductors — the lightning will pass through him,

or in other words, he will be struck. Another individual standing at the distance of only a few feet, — but *out of such a series*, will be safe. This subject has however been more fully discussed in our Tract on the Weather.

3. *It produces no sensible effects when passing through conductors.*

Its motion is instantaneous as was before shown, at least it passes with inconceivable velocity; but it produces no perceptible effects, when it passes through good conductors. Let a large wire be held in the hand, one end touching the knob connected with the inside of a Leyden jar, and then let an assistant, by means of a discharger, bring the other end into connexion with the knob. The charge will immediately pass from the knob through the discharger to the wire, and through the wire as it lies in the hand to the outside of the jar. Now, however attentively the performer may examine the wire, at the instant of the passing of the discharge, no perceptible effect of any kind can be observed. There is no motion, no heat, and no light, and the hand does not feel the shock in the slightest degree.

When, however, the accumulated fluid, on its passage to its place of destination finds *its progress interrupted*, it then produces its most marked and striking effects. Some of these we shall now notice. The violence of the effect is proportioned to the degree of interruption. The air is a non-conductor. If it has, therefore, to pass through the air at an interruption in its circuit, the most striking of its effects are produced. This brings us then to our fourth particular.

4. *Electrical light.*

It is impossible to use the electric machine at all, without perceiving that the fluid evolves light whenever it passes through the air. The jar cannot be discharged without producing this effect, for if one end of the discharger is brought into contact with the outside, and the other is made to approach the knob, before it touches it, the fluid will dart across, exhibiting the bright light which the fluid always produces when passing through the air.

The appearance of this spark is somewhat peculiar. It is usually of bright yellow at the extremities, and bluish in the middle. In discharging a Leyden jar, it is short and intense in brightness;—when taken from a prime conductor, it is much longer and fainter. The length of the spark which can be drawn from a conductor depends upon the size of the machine, and the condition which it is in at the time of the experiment. Sparks can without much difficulty be obtained several inches in length.

If, in receiving the spark from the conductor, the operator, instead of presenting a small body like a brass ball, presents a *large flat surface*, like the back of the hand, and if this surface is held at a considerable distance, the spark at a little distance from the prime conductor will branch off into many beautiful ramifications, presenting in the night, and under favorable circumstances, a splendid tree of fire. The size and beauty of this tree will depend of course very much upon the excellence of the machine, and the circumstances under which the experiment is made.

This tendency of the electric fluid to give light whenever it passes through the air, produces many other remarkable appearances, in working the machine in the dark. Long sparks dart from the prime conductor to the rubber. Bright lines and spots of light, ornament the under surface of the rubber,—and flashes and trees of flame dart from side to side. These beautiful appearances can only however be seen when the circumstances are highly favorable.

There are many cases of common occurrence in which this electric light appears. It is common for children to amuse themselves by rubbing the back of a cat in the dark, to observe the sparks thus produced. These are electrical, the fur of the cat being a most excellent electric. A silk or flannel garment, will often when taken off sparkle,—and many a child, has, in a cold winter night, been frightened at seeing sparks in his bed, as he opens the blankets. The Aurora Borealis is generally supposed, though without much direct proof, to be an electrical effect.

There are many beautiful experiments designed to exhibit in a striking way the illuminating power of electricity. Some of these we shall describe.

The spiral tube. This consists of a common glass tube with little circular pieces of tin foil pasted upon it, so as to be as near each other as possible without touching. These pieces are arranged in such a manner that they pass round the tube in a spiral form, one end of which is to be connected with the prime conductor. On turning the machine the conductor becomes charged, and the fluid passes off through these discs of tinfoil, producing a spark at each interruption;—and as the passage is instantaneous, the appearance is that of a beautiful spiral line of light. The operator sometimes endeavors to perform this experiment by means of the Leyden jar. It is, however, a remarkable fact which we do not recollect to have seen noticed in any treatise, that very many of the experiments with electric light, succeed altogether better with the *conductor* than with the jar. The conductor gives a longer spark, and the charge from it forces its way through a much longer series of interruptions.

The spiral tube prepared as above described, is often inclosed in another tube a little larger, so that the tin-foil is protected from injury. Sometimes, instead of a tube, a flat plate of glass is used, and the circles of tin-foil or of sheet lead are pasted upon it in any way that fancy may direct. The interruptions are sometimes so arranged that the letters of a word are pictured in light, — or a profile, — or a rude sketch of any kind. Sometimes a long and narrow plate of glass has a serpentine row of discs of tin foil upon one side, while the other is painted with transparent colors, which gives to the light a variety of hues.

The luminous jar. A Leyden jar is coated with detached pieces of tin foil coming almost into contact with each other, instead of having the ordinary continuous covering. While this is charging, sparks will be seen darting from one piece of the tinfoil to another, illuminating the whole surface in a beautiful manner.

The illuminated thumb. If two wires lying upon the

table, be brought within a third of an inch of each other, and the thumb is pressed upon the table so as to touch the two ends of the wire, and to cover the whole place of the interruption, and a strong spark be passed through the apparatus thus arranged, the flesh of the finger will be strongly illuminated.

The electric light exhibited in these various experiments does not depend at all upon the nature of the substance which is charged. If a person stands upon the insulating stool in the manner before described, and is charged, sparks may be drawn from his hands, his face, or any part of the body. A tumbler of water or a mass of ice, may be charged, and sparks taken from its surfaces. It is the *simple passage of the electricity through the air*, which produces the effect.

Illuminated water. Although water is classed among conductors, still the resistance it makes to the passage of the electricity is such, that when it is made a part of the circuit, a very distinct light is evolved. A moderate charge will produce a bright spark when made to pass through water, and the spark is still more luminous in oil, alcohol, or ether, which are worse conductors than water. On the contrary, in fluids of greater conducting power, there is greater difficulty in eliciting electric light. Thus a much higher charge is required to produce a spark in hot water than in cold; a still higher in saline solutions; and in concentrated acids light can be obtained only when their volume is very small; so that it is necessary for that purpose to draw a line of the acid upon a plate of glass with a camel's hair pencil. This is illustrated by the following experiment. Draw a line with a pen dipped in water on the surface of a slip of glass; place one extremity of the line in contact with the coating of a Leyden jar, and at six inches' distance place upon the line one knob of the discharging rod. When the jar is fully charged, bring the other ball of the discharged to the knob of the jar, and the discharge will take place luminously over the six inches of water. Next, trace a line with a pen dipped in sulphuric acid on a slip of glass, as in the former experiment, and place one extremity of it in contact with the outside of the jar; the

ball of the discharger may then be placed on the glass at twelve inches' distance, and the electric fluid will pass as brilliantly over that interval as over the six inches of water. In either of these experiments if the line of fluid be wider in any particular part, the light of the discharge will be less brilliant in passing that portion.

5. *Electrical heat.*

The electrical spark develops *heat* as well as light, as may be shown in a great variety of ways. Some experiments for this purpose we shall enumerate.

Inflaming combustibles. Sprinkle upon a light tuft of cotton a quantity of powdered resin, and shake the cotton until the resin has penetrated it in every part. Bring then two wires with rounded ends, very near each other, but with the cotton between. Pass now a strong spark from the Leyden jar through the cotton, and it will burst into a flame.

Pour into a metallic cup attached to the prime conductor, a little ether or alcohol, and then when the conductor is charged, draw a bright spark from the centre of the surface of the liquid. It will be immediately inflamed. Sometimes the experiment is made in another form. Instead of the cup attached to the conductor, a person standing upon the insulating stool, holds an iron spoon containing the alcohol or ether, and a bystander takes the spark from it by means of a brass ball, or his knuckle, or even a piece of ice.

Detonating mixtures of gases, — especially hydrogen gas and atmospheric air, — may be fired by means of electricity. Sometimes they are contained in a strong glass vessel, with two wires coming on the inside within a short distance of each other. Sometimes a little brass cannon is used, loaded with the explosive gases, and the muzzle stopped with a cork, — the said cork being thrown with considerable force among the bystanders by the discharge, to the no small amusement of such of them as do not chance to be shot.

Gunpowder may be fired by the electric spark, under favorable circumstances. In all cases the combustible to be inflamed should be previously warmed.

Metling metals. It has before been observed that the electric fluid produces no sensible effect when passing through conductors. If, however, the conductor is so slender that only a part of the fluid can pass upon it, the rest, surrounding it, but passing through the air, gives out light and heat. By this heat a narrow strip of gold or silver leaf—a slender, thread-like cutting of tinfoil,—or even a very fine wire, may be melted by passing a strong charge from a battery through them.

The degree of heat which is evolved by the passage of electricity through any substance, depends upon the degree of resistance which the substance opposes. The more perfect the conductor the less the heat. If the metal is one of those which are the most perfect conductors, it will require a larger charge to produce a sensible effect in warming it. Wood is a very imperfect conductor,—consequently a small quantity of electricity will affect its temperature, and a piece of considerable thickness may be warmed by repeated discharges.

In consequence of this fact, that the *conducting power* of the metal upon which the experiment is tried, influences very much the degree of heat evolved by the transmission of electricity through it, some philosophers have endeavored to ascertain the different conducting powers of the metals, by observing the comparative difficulty with which they are melted by electricity. The experiments may be performed in the following way.

Connect with the outside coating of a battery, which, in order to secure the success of the experiment, should contain at least thirty square feet of coated surface, a wire of one fiftieth of an inch in diameter, and two feet long. With a smaller battery, the experiment will succeed, if the experimenter is satisfied with a shorter or slenderer wire. The other end of the wire must be fastened to the end of a discharging rod. When the battery is fully charged, the ball of the discharger may be brought into connexion with the knob communicating with the outside of the battery, and thus the whole charge will be sent through the wire, which will be made red hot through its whole extent, and even melted so as to fall in glowing pieces to the floor. When a wire

melted in this manner, sparks are frequently seen at considerable distance from it, which are red hot particles of the metal, that by the violence of the explosion, are thrown in all directions. If the force of the battery be very great, the wire will be entirely dispersed by the explosion so that none of it can afterwards be found.'

— By repeating this experiment with wires of different metals, and using the same quantity of electrical power, that is, by using the same battery and charging it to the same degree of intensity, it will be found that some metals are fused more readily than others, whilst some are not sensibly affected. This shows the difference of their conducting powers. Some are melted instantaneously through their whole length, and entirely dispersed by the force of the explosion. Others merely melt and drop in globules. Others still, become red hot — or are even only heated at the ends. An electrician once had a number of wires prepared of various metals, — all of the same diameter, one thirtysecond of an inch. He used a very large electrical machine, to which was attached a battery containing 225 feet of coated surface. The wires were of equal lengths, and the battery charged to the same degree of intensity in all the experiments. The following was the result. Of the *lead* wire 120 inches were melted; — of *tin* the same. *Iron* wire only *five* inches; — *gold* wire three inches and a half. *Silver*, *copper* and *brass* wire, only one quarter of an inch.

Some writers on electricity have considered these experiments as showing directly the conducting powers of these metals, — supposing them to be inversely as the fusibility. It seem more probable that the conducting power is inversely as the *heat* produced, and as it requires much less heat to fuse lead than brass, the lead, even if an equally good conductor, would be much more easily fused.

The philosopher above alluded to, had the curiosity to try the experiment of fusing these metals under water, — and the plan succeeded. It was necessary, however, to use much shorter wires. The same discharge would generally melt *one eighth part* as much wire under water, as in the open air.

The most suitable substances upon which to make experiments on the fusibility of metals with small machines, are gold, silver or brass leaf, — or even tin foil cut into very slender strips, — or a very fine flattened steel wire, used by watchmakers, called watch pendulum wire. By means of either of these, fusion may often be produced by a common machine and by a single Leyden jar.

Heat evolved by lightning. The power of those immense charges of electricity which descend from the clouds, to inflame combustibles and fuse metals is a matter of common observation. Small pieces of iron, i. e. too small for the whole quantity of the fluid to pass them, are melted. It must be borne constantly in mind that this heat is developed only when the conducting substances are not sufficient to convey off the electricity freely to the ground. There is no evidence that a common lightning rod, down which the electricity passes freely, becomes in the least degree warmed by its power. The points, however, at the top, are frequently fused.

A house was once struck with lightning, and a pair of tongs which were standing up against the fireplace were thrown down. A person standing in the room, who fortunately was not injured by the shock, almost immediately took them up, and on examining them was surprised to find, that although the iron was cold as usual to the touch, yet at the two extremities of the tongs, — apparently at the places where the fluid entered, and left, — there were two *small melted spots*. The iron was very distinctly and evidently fused — and the individual was much surprised that the heat should be so great as to melt the iron in any part, and yet not to heat it throughout so as to render its warmth sensible to the hand. But the fact is that the electric fluid is not, as many suppose, hot itself. It *produces heat*, when passing through the air. It will do this when coming out of ice, as well as when coming from a metal; and in the case above described, the electric fluid, developed heat in coming through the air *to* the tongs, and in passing through the air *from* the tongs, in sufficient quantities to fuse the metal at the points where it entered, and where it left.

6. *Influence of balls and points.*

It has before been stated under the head *Distribution of Electricity*, that the fluid accumulates itself in a state of great intensity at the *pointed extremities* of a charged body, where it passes off in continued streams. On this account a body containing any sharp or pointed parts, can with great difficulty be charged with electricity.

On the other hand if a body with all its extremities properly rounded, is charged and brought, when in that state, into the vicinity of any pointed bodies, its electricity is immediately and rapidly drawn off. So marked and powerful is this effect that the greatest care is necessary, or the successful operation of the machine will be entirely prevented by the accidental presence of pointed substances in the vicinity. To avoid this every part of the machine and of the apparatus about it, should be rounded, — every wire should be terminated by a ball, — no roughness or raggedness of any kind should be left, — all dust should be removed, and every sharp or pointed body should be taken away from the vicinity. A sharp needle, held at the distance of several feet from the prime conductor, will often effectually prevent its being charged. There are various distinct experiments by which this influence of points may be strikingly shown.

1. Attempt to charge the prime conductor and while doing so hold at a little distance from it a needle with the point towards it. The effort to charge the conductor will be vain, — the electricity will pass off to the point as fast as it enters the conductor, and in the dark, a luminous star will be seen upon the point of the needle.

2. After the jar is charged bring a brass ball to it, and observe the size of the spark. Then charge it again and attempt to obtain a similar spark by means of a *pointed body*. The result will be that the electricity will pass to the point silently, before it comes near enough for the spark.

3. The *discharger*, heretofore described, is usually made with balls at the extremities, so constructed that they may be unscrewed, leaving the extremities of the wire pointed. If now the jar be charged, and then dis-

charged in the ordinary way by using the balls of the discharger, a bright spark will pass. Unscrew then one of the balls, — charge the jar again, and attempt to discharge it by bringing up the *point* to the knob of the jar. It will be found that the rapid passing off of the electricity through the point, will prevent any spark.

4. 'Take a small lock of cotton, extend it in every direction as much as may be practicable, and by means of a linen thread, about five or six inches long, or by a thread drawn out of the same cotton, tie it to the end of the prime conductor; then let the electrical machine be put in action, and the lock of cotton, on being electrified, will immediately swell out, by repelling its filaments from each other, and will stretch itself towards the nearest conductor. In this situation, the machine continuing in action, present the end of a finger, or the knob of a wire, towards the lock of cotton, and this will then immediately move towards the finger, endeavoring to touch it. But take a sharp pointed needle in the other hand, and present its points towards the cotton, a little above the end of the above-mentioned finger, and you will find that the cotton immediately shrinks upwards, and moves towards the prime conductor. Remove the needle, and the cotton will come again towards the finger. Present the needle, and the cotton will shrink again; which clearly shows that the needle, being sharp pointed, draws off the electric fluid from the cotton, and puts it in a state of being attracted by the prime conductor; which effect cannot be produced by a wire having a blunted end, or a round ball for its termination.'

5. *Lightning rods.* 'The philosophy of lightning rods is very evident from the foregoing remarks. The rod itself forms a conductor from the top of the house to the ground, and by being terminated above by sharp points, the electricity of the cloud is drawn off silently. Whenever a thunder cloud passes a house which has a lightning rod, the fluid passes down the rod constantly in a silent and harmless stream. So great is this effect, that it is said that in a large city like London where there are many lightning rods, the thunder showers lose half their violence. When the cloud, which, as it passes over the

fields and forests, sends forth its thunderings and lightnings incessantly, comes over the pointed rods of the city, its charge is drawn off, almost as rapidly as it gathers,—the flashes are less frequent and less vivid, and everything indicates the mitigation of the storm.

If a point proceeds from any electrified body, there is always to be observed issuing from it a current of air. This is the case whichever way the body is electrified. Let a sharp point be attached to the prime conductor, and then 'present the face, or the palm of the hand, to the point at the distance of about three inches, and a wind will be perceived to proceed from it.

'Fasten five or six pieces of paper to a cork, like the leaves of a water wheel in hydraulics; pass a needle, by way of an axis, through the cork, and suspend it by applying the end of the needle to a magnet. Let a pointed wire be fixed at the end of the prime conductor, and present the paper vanes of the cork suspended, &c, to the current of air which proceeds from that point, when the machine is in action; and the force of that wind will cause the cork to turn round.

'This current of air always proceeds from the point, whether the point be electrified positively or negatively: therefore it is not the influx or the efflux of the electric fluid that occasions the wind; but it is owing to the particles of air which, acquiring the same electricity as the pointed wire, are repelled from it in virtue of the repulsion which takes place between bodies possessed of the same kind of electricity, be it positive or negative. Other particles of air succeed those which are repelled first, and these being electrified are also repelled, and so on.

'When the wire, instead of a pointed termination, is furnished with a ball of about an inch and a quarter in diameter, a curious phenomenon may be observed, by presenting the flame of a candle to it, viz. so that the middle of the flame may be even with the middle of the ball. The machine being put in action, it will be found that the flame is blown from the ball, when the latter is electrified positively, viz. when it is connected with the rubber of the machine, or with a negative prime conductor; which seems to show the real influx and efflux of the electric fluid, according to the Franklinian theory.'

7. *Mechanical effects of electricity.*

Whenever a large charge of the electric fluid passes through or among bodies of very little conducting power, it seems to exert no little *mechanical force* in preforating, rupturing, or dispersing them. These experiments may be performed in a variety of ways.

Perforating paper. Let a card of ordinary thickness, be laid upon the table, with a piece of tin foil under it, one end of which is connected with the outside of the Leyden jar. Place one knob of the discharger, on the top of the card, and bring the other into contact with the knob or inside of the jar. In this way the spark, if it passes at all, will pass through the paper, and on examining it, a small perforation will be found to be made, — and if the charge is great several perforations.

There is something very singular in the appearance of these perforations. The paper is protruded *on both sides*, — forming a sort of double bur, one looking down towards the tinfoil, and the other up towards the knob of the discharger. In former times when the controversy between the supporters of the two theories, — those of Franklin and Du Faye, — was going on, this experiment was considered by many as very decisive proof of the opposite motion of two fluids. It seems, however, not probable that the protrusion of the paper is owing to the mechanical impetus of the two fluids, but to the very violent and sudden rarification of the air contained in the substance of the paper, which by the explosive force thus given it, forces the parts of the paper out each way.

This experiment may be varied by using not a card, but several sheets of paper, a quire, or twenty or thirty leaves of a book. The effect will be precisely analogous. The separate leaves will be protruded from the middle sheet outwards, each way.

Perforation of glass. If instead of a sheet of paper a thin plate of glass be used, it will be shivered to fragments at the spot where the electricity passes, perhaps, however, without falling to pieces. In one small spot the glass will be completely pulverized, and from that spot cracks will radiate to a greater or less distance ac-

cording to the force of the discharge. The most common case in which this effect is seen is in what is called the spontaneous discharge of a Leyden jar. When a jar formed of thin glass, is very highly charged it sometimes discharges itself through the glass itself, producing the appearances above described, with this addition, however, that the tinfoil is protruded, both on the inside and outside, forming in both cases a large and conspicuous bur. This result seems to confirm the opinion stated above, that these protrusions are owing to the explosive force of highly rarified air, or to some similar cause, rather than to the impetus of the fluid, for the glass, at the place of fracture, is completely pulverized, but it is not displaced, yet the tinfoil is displaced, there being between it and the glass a quantity of air mingled with the paste or other cementing substance.

'The expansion of air by the passage of the electrical fluid, either in the form of sparks or shocks, is shown in the following experiment of Kinnersley, the apparatus for which has been called the electrical air thermometer. It consists, of a glass tube closed at both ends by air-tight brass caps, through which two wires slide in the direction of the axis of the tube. These wires are terminated by brass balls, which are made to approach within the striking distance. To an aperture in the bottom of the lower cap, is fitted a bent tube of glass which turns upwards, and is open at both ends; the bent part is filled with mercury, or with a colored fluid, which may indicate by its rising or falling in the tube, any dilatation or contraction that may take place in the air within the vessel. It is found that every time a spark passes between the brass balls, the fluid suddenly rises, but descends again to its former level immediately after each explosion; thus showing that the dilatation of the air, produced by the abrupt passage of electricity, is but of momentary duration.

‘When a strong electrical charge is sent through a very confined portion of air, the explosive effects produced by it, are as considerable as those we have seen exhibited by denser fluids. Thus if a piece of plate glass, of the size of a square inch, and half an inch in thick-

ness, be laid flat upon a table, and pressed down by a weight, and the points of the wires be set opposite to each other and against the under edge of the glass, so that the electricity may pass beneath it, the charge of a large jar transmitted in this way will break the glass into innumerable fragments, and even reduce a portion into an impalpable powder. If the mouth of a small mortar made of ivory, with a cavity of half an inch diameter, and an inch deep, stopped by a cork, fitted so as to close the aperture accurately, yet without much friction, and if two wires be inserted through the sides of the mortar so that their points within the cavity, be separated by an interval of about a quarter of an inch, a strong charge being sent through the wires will expand the air within the cavity so suddenly as to project the cork to some distance.

‘Solid bodies of a porous texture, such as wood, are easily torn asunder by an electric charge. If two holes be drilled in the opposite ends of a piece of wood, about half an inch long, and a quarter of an inch thick, and the ends of two wires inserted in the holes, so that their points may heat the distance of a quarter of an inch, on passing a strong charge the wood will be split in pieces. Stones, loaf-sugar, and other brittle and imperfectly conducting substances, may be broken in a similar way.

‘Place a piece of dry writing paper upon the table of the universal discharger, and having removed the balls from the ends of the sliding wires, press the points of the wires against the paper at the distance of two inches from each other, if a powerful shock be now sent through the wires, the paper will be torn in pieces. If a number of wafers be placed on the table instead of paper they will be dispersed in a curious manner, and many of them broken into small fragments.

The thunder house. This is an apparatus designed to show the efficacy of a lightning rod in preventing the violent effects of lightning. It contains in the side of a little wooden house, a square piece of wood, which when the little lightning rod is interrupted in its course, is thrown out with violence.

Violent effects of lightning. We have already mentioned the light and the heat evolved by the electric fluid from the clouds, but the mechanical effects of its violence are, if possible, still more striking. In passing down through a floor, it sometimes perforates it in many places. It knocks down walls, breaks panes of glass, — and tears and splits the largest trees. A case is described in Silliman's Journal of Science, in which the clothes of a man standing at the door of his house, were torn into utter fragments. He was rendered senseless by the shock but soon recovered.

8. *Effect of electricity upon the animal system.*

If the knuckle of the operator is brought to the prime conductor, when it is charged, — the spark is received, and a slight pricking sensation is felt. If the spark is very large, a sudden and very peculiar sensation is felt through the joint. It is very slightly painful.

When, however, the Leyden jar is used, and the performer grasps the outside with one hand and touches the knob with the other, a very peculiar, and if the charge is large, a very painful sensation, called the electric shock, is felt through the arms and chest. If several individuals unite by joining hands, and at one end of the line a connexion is formed with the outside, and at the other end with the inside of the jar, they will all perceive the shock at the same instant. It produces a painful feeling at the joints, attended by a convulsive twitch, which causes an involuntary start. Some persons are much more easily affected than others. In many cases young persons are fond of taking the shocks, — to others they are highly disagreeable.

When this singular effect of electricity was originally discovered, the philosophers who first experienced the shock in their own persons, were 'so impressed with wonder and with terror by this novel sensation, that they wrote the most ridiculous and exaggerated account of their feelings on the occasion. Muschenbroek states, that he received so dreadful a concussion in his arms, shoulder, and heart, that he lost his breath, and that it was two days before he could recover from its effects; he

declared also that he should not be induced to take another shock for the whole kingdom of France. Mr Allemand reports, that the shock deprived him of breath for some minutes, and afterwards produced so acute a pain along his right arm, that he was apprehensive it might be attended with serious consequences. Mr Winkler informs us, that it threw his whole body into convulsions, and excited such a ferment in his blood, as would have thrown him into a fever, but for the timely employment of febrifuge remedies. He states, that at another time it produced copious bleeding at the nose; the same effect was produced also upon his lady, who was almost rendered incapable of walking. These strange accounts naturally excited the attention and wonder of all classes of people; the learned and the vulgar were equally desirous of experiencing so singular a sensation, and great numbers of half-taught electricians wandered through every part of Europe, to gratify this universal curiosity.

The shock is, however, perfectly harmless, at least when obtained from any common sized Leyden jar. The unpleasant feeling passes off in a moment, and though in the use of an electric machine, the performer is continually liable to allow the charge to pass through his system unintentionally, — and indeed accidents of this kind very often happen — yet we are not aware that any serious effects have in any case resulted. The safety is, however, owing entirely to the smallness of the quantity of electricity which can be accumulated with the common apparatus.

The electric fluid when collected in sufficient quantities, and caused to pass through the animal frame, — destroys life at once. It is common to show this by killing small animals, with Leyden jars or a battery. A square foot of coated surface will take the life of an animal of the size of a rat or a squirrel. With large batteries the same effect may be produced upon larger animals. The experiments are, however, not very pleasant to be performed, and the results may perhaps as well be taken upon trust.

The fluid seems to act most directly upon the nervous

system, and its power here has been employed extensively for medical purposes. The benefits resulting have been at some periods highly exaggerated, but there is perhaps no doubt that in many diseases the effects of this agent are salutary.

‘Electricity may be administered medicinally in four different ways. The first and most gentle is under the form of a continued stream, or aura as it is termed, derived from a wire or pointed piece of wood connected with the prime conductor, and held at the distance of one or two inches from the point to which it is to be directed; an impression is felt similar to a current of air; and in this way it may be borne by parts of great sensibility, such as the eye. The second mode is by directing sparks of various sizes to the affected part, by means of a metallic ball at the extremity of a brass rod, which is within a moderate distance from the part; or else by placing the patient on an insulating stool, and while he is in communication with the prime conductor of the machine, taking sparks from him by another person with a metallic ball at the end of a rod which he holds in his hand. The size and intensity of the sparks will, of course, be regulated by the distance at which the ball is placed from the body, provided the machine be steadily worked. The third mode is that by shocks from the discharge of a Leyden phial, which is, of course, the most severe and painful method of applying electricity. Great caution is required against the indiscriminate application of this last method, which is not wholly free from danger.’

We have thus presented a brief, and it has been intended to be, a simple view of the science of electricity. Our design has been to give in the confined space allotted to us, as full a description of the nature and effects of this mysterious agent, as is in our power.

Some very interesting incidents which have occurred in the history of this science, we should have been glad to have presented, if our limits had allowed. We cannot, however, forbear quoting in the conclusion of our treatise, the following description of Franklin's experiments to identify the electric fluid and the lightning of the clouds.

‘Dr Franklin was so impressed with the many points of resemblance between lightning and electricity, that he was convinced of their identity, and determined to ascertain by direct experiment the truth of his bold conjecture. A spire which was erecting in Philadelphia he conceived might assist him in this inquiry ; but, while waiting for its completion, the sight of a boy’s kite, which had been raised for amusement, immediately suggested to him a more ready method of attaining his object. Having constructed a kite by stretching a large silk handkerchief over two sticks in the form of a cross, on the first appearance of an approaching storm, in June, 1752, he went out into a field, accompanied by his son, to whom alone he had imparted his design. Having raised his kite, and attached a key to the lower end of the hempen string, he insulated it by fastening it to a post, by means of a silk string, and waited with intense interest for the result. A considerable time elapsed without the apparatus giving any sign of electricity, even although a dense cloud, apparently charged with lightning, had passed over the spot on which they stood. Franklin was just beginning to despair of success, when his attention was caught by the bristling up of some of the loose fibres on the hempen cord ; he immediately presented his knuckle to the key, and received an electric spark. Overcome with the emotion inspired by this decisive evidence of the great discovery he had achieved, he heaved a deep sigh, and conscious of an immortal name, felt he could have been content if that moment had been his last. The rain now fell in torrents, and wetting the string, rendered it conducting in its whole length ; so that electric sparks were now collected from it in great abundance.

‘It should be noticed, however, that about a month before Franklin made these successful trials, some philosophers had obtained similar results in France, by following the plan recommended by Franklin. But the glory of the discovery is universally given to Franklin, as it was from his suggestions that the methods of obtaining it were originally derived.

‘This important discovery was prosecuted with great

ardor by philosophers in every part of Europe. The first experimenters incurred considerable risk in their attempts to draw down electricity from the clouds, as was soon proved by the fatal catastrophe, which, on the sixth of August, befel Professor Richman, of Petersburg, whose name has been already before us. He had constructed an apparatus for observations on atmospheric electricity, and was attending a meeting of the Academy of Sciences, when the sound of distant thunder caught his ear. He immediately hastened home, taking with him his engraver, Sokolon, that he might delineate the appearances that might present themselves. While intent upon examining the electrometer, a large globe of fire flashed from the conducting rod, which was insulated, to the head of Richman, and passing through his body, instantly deprived him of life. A red spot was found on his forehead, where the electricity had entered, his shoe was burst open, and part of his clothes singed. His companion was struck down, and remained senseless for some time; the door case of the room was split, and the door itself torn off its hinges.'

AGENTS

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SCIENTIFIC TRACTS.

NUMBER XXII.

MILITARY PROJECTILES.

ANALYSIS.

Nature of the path of a projectile. Primitive contrivances; Simple human strength; Sling; Dart. Elasticity of various substances. Bow and Arrow; Ballista; Catapulta. Description of the siege of Syracuse.

Invention of gunpowder. Cannon. Mortars. Shells. Carcasses. Description of the shelling of a fort in India. Howitzers, Caronades. Portable fire-arms. Theory of the rifle. History of the science of Gunnery. Calculations and experiments. Eprouvette. Ballistic Pendulum.

THEORY OF PROJECTILES.

Whenever a body is projected, as for example, a cannon ball, it is plain that it is acted upon by two forces, *the attraction of gravitation* drawing it towards the earth, and the *impelling force*, whatever that may be. In order, then, to ascertain the path of the body, we must consider the nature of these two forces, first, separately, and then in their united action upon the body projected.

It has been already shown in our tract on Gravitation, that bodies when falling freely, descend in the first second 16.1 feet, in the next second 48.3, making in the two 64.4, or four times the space passed over in one. In the same manner, in *three* seconds, a body will fall *nine* times as far as in one, and in four seconds sixteen times as far; — and, universally, *the space through which the body will descend will be as the square of the time.*

This accelerated motion may be easily represented to the eye thus: —

In this line each little division represents 16.1 feet, as that is the space through which a body falls in the first second.

The other force to which a projected body is subject, is the *impulse* which is given it. This is much more simple in its character, for, if we leave out of the consideration the resistance of the air, the effect of this impulse is uniform. Motion once imparted continues unchanged, unless some foreign force affects it. Consequently, the tendency of the force of impulse is to carry forward the body uniformly in a straight line.

These two forces now must be combined in order to show the real path of the projectile. Their combination is usually illustrated by the following diagram.

The line oc represents the tendency of *gravitation*, with the seconds marked on the left; $o4'b$ represents the tendency of the *projectile force*, which being uniform, the line is divided into equal parts, which are marked by the seconds above. These parts compared with one of the divisions of the perpendicular line appear to be about five times as long;

and as these divisions stand for about sixteen feet, the divisions of the other line would represent about seven-

tyfive feet each; — so that the figure corresponds with the condition of a body thrown a little upwards with a velocity of about seventyfive feet per second. Now the effect of the projectile force will be to carry it on, during the first second, as far as bl' , while during the same time, *gravitation* will bring it down from the point bl' which it would have reached, as much as the distance from o to al' . The point then at which the body will be found is m . In the same manner we find the points n, o, p , the successive places of the body at the end of the second, third, and fourth seconds. The whole path of the projectile will be the curve o, m, n, o, p .

It is not our present purpose to go any farther into the theory of projectiles, but to give some practical information, for the benefit of the general reader, in regard to the contrivances for propelling heavy bodies for the purposes of war. The above theoretical view was necessary to illustrate some remarks to be made in the sequel.

PRIMITIVE CONTRIVANCES.

1. The *unassisted strength of the human arm* was the first force which was applied to the purpose of projecting bodies for offensive purposes. Stones, clubs and spears were the first rude weapons. The muscular strength which gives motion to such projectiles is not, strictly speaking, directly applied to them by impulse. It is employed in giving a circular motion to the arm, the body to be projected being thrown off by the *centrifugal* force. Consequently the force given to the projectile will be proportional, not only to the *strength* of the individual, but to the *length of his arm*, as this would increase the length of the arc through which the hand moves, and consequently its velocity. A very obvious mode of increasing the power, therefore, would be to increase by artificial means this length, which gives rise to the construction of the second species of weapons.

2. The *sling and the dart*, two modes of projecting bodies which evidently derive their power from increasing the velocity of the projectile, by increasing the *arc through which it moves*, and which differ from each other,

only in the trifling difference of the purposes to which they were applied. The sling being intended to throw a stone, and the dart, a sort of arrow.

3. The third class comprises those in which the *elastic force* of various substances is applied to the projectile. The bow and arrow is the simplest instrument of this kind, and it was for a long time in earlier ages, one of the most important means of warfare. Hand-bows were constructed of various materials, and fitted up in very various ways. The accuracy with which they may be aimed, and the greater velocity which may be given to the projectile, enabled them to take a high rank in the time when they were introduced.

As men advanced in the arts of life, and began to feel the necessity of having some permanent means of defence, walls and fortifications of various kinds began to be erected, which were for a long time an effectual security from violence. The same principle, however, with that which gives its efficiency to the bow and arrow, soon afforded the means of successful attack against these. The engines so frequently mentioned in ancient history under the names of Balista — Catapulta — Onager, &c, — were variously constructed ; but the force was usually the elasticity of twisted ropes. The construction and the employment of these and similar engines, continued for some time in the middle ages. They received various names, and were variously modified according to the ingenuity, or the particular purposes of the engineers who prepared them.

It is not possible to ascertain now with any accuracy, what was the form, or how great the power of these engines. The most exaggerated accounts of their magnitude and effects have descended to us, and whatever deduction it is necessary to make from these, it is doubtless true, that immense stones, and beams of wood, and other ponderous missiles of great size were thrown by these machines with great force and effect. The following extract from Plutarch's account of the siege of Syracuse, will illustrate the use of these and similar engines.

'Archimedes one day asserted to king Hiero, whose kinsman and friend he was, this proposition, that with a

given power he could move any given weight whatever ; nay, it is said, from the confidence he had in his demonstration, he ventured to affirm, that if there was another earth besides this we inhabit, by going into that, he would move this wherever he pleased. Hiero, full of wonder, begged of him to evince the truth of his proposition, by moving some great weight with a small power. In compliance with which, Archimedes caused one of the king's galleys to be drawn on shore, with many hands and much labor ; and having well manned her, and put on board her usual loading, he placed himself at a distance, and without any pains, only moving with his hand the end of a machine, which consisted of a variety of ropes and pulleys, he drew her to him in as smooth and gentle a manner as if she had been under full sail. The king quite astonished when he saw the force of his art, prevailed upon Archimedes to make for him all manner of engines and machines which could be used either for attack or defence in a siege. These, however, he never made use of, the greatest part of his reign being blessed with tranquillity ; but they were extremely serviceable to the Syracusans on the present occasion, who, with such a number of machines, had the inventor to direct them.

‘ When the Romans attacked them both by sea and land, they were struck dumb with terror, imagining they could not possibly resist such numerous forces and so furious an assault. But Archimedes soon began to play his engines, and they shot against the land forces, all sorts of missive weapons, and stones of an enormous size, with so incredible a noise and rapidity, that nothing could stand before them ; they overturned and crushed whatever came in their way, and spread terrible disorder throughout the ranks. On the side towards the sea were erected vast machines, putting forth on a sudden over the walls, huge beams, which striking with a prodigious force on the enemy's galleys, sunk them at once ; while other ships hoisted up at the prows by iron grapples or hooks, like the beaks of cranes, and set an end on the stern, were plunged to the bottom of the sea ; and others again by ropes and grapples were drawn towards the shore, and after being whirled about, and dashed against the rocks

that projected below the walls, were broken to pieces, and the crew perished. Very often a ship lifted high above the sea, suspended and twirling in the air, presented a most dreadful spectacle. There it swung till the men were thrown out by the violence of the motion, and then it split against the walls, or sunk, on the engines letting go its hold. As for the machine which Marcellus brought forward upon eight galleys, and which was called *sambuca* on account of its likeness to the musical instrument of that name, whilst it was at a considerable distance from the wall, Archimedes discharged a stone of ten talents' weight, and after that a second and a third, all which striking upon it with amazing noise and force, shattered and totally disjoined it.

'Marcellus, in his distress, drew off his galleys as fast as possible, and sent orders to the land forces to retreat likewise. He then called a council of war, in which it was resolved, to come close to the walls, if it was possible, next day before morning. For Archimedes' engines, they thought, being very strong, and intending to act at a considerable distance, would then discharge themselves over their heads; and if they were pointed at them when so near, would have no effect. But for this Archimedes had long been prepared, having by him engines fitted to all distances, with suitable weapons and shorter beams. Besides, he had caused holes to be made in the walls, in which he had placed *scorpions*, that did not carry far, but could be fast discharged, and by these the enemy was galled, without knowing whence the weapon came.

'When, therefore, the Romans got close to the walls, undiscovered, as they thought, they were welcomed with a shower of darts, and huge pieces of rocks, which fell as it were perpendicularly on their heads; for the engines played from every quarter of the walls. This obliged them to retire; and when they were at some distance, other shafts were shot at them, in their retreat, from the larger machines, which made terrible havoc among them as well as greatly damaged their shipping, without any possibility of their annoying the Syracusans in their turn; for Archimedes had placed most of his engines under

covert of the walls; so that the Romans, being infinitely distressed by an invisible enemy, seemed to fight against the gods.

‘Marcellus, however, got off, and laughed at his own artillery men and engineers. “Why do we not leave off contending,” said he, “with this mathematical Briareus, who sitting on the shore, and acting as it were but in jest, has shamefully baffled our naval assault; and, in striking us with such a multitude of bolts at once, exceeds even the hundred giants in the fable?” And, in truth all the rest of the Syracusans were no more than the body in the batteries of Archimedes, while he himself was the informing soul. All other weapons lay idle and unemployed; his were the only offensive and defensive arms of the city. At last the Romans were so terrified, that if they saw but a rope or stick put over the walls, they cried out that Archimedes was levelling some machine at them, and turned their backs and fled. Marcellus, seeing this, gave up all thoughts of proceeding by assault, and leaving the matter to time, turned the siege into a blockade.’

Such is Plutarch’s account. ‘The reader may perhaps look a little incredulous at the idea of ships being hooked up into the air, and whirled round against rocks and walls till they are dashed to pieces—and even at some other parts of this account. But, however, exaggerated it may be in its details, there is no question that Archimedes brought on this occasion an immense mechanical power to bear on the work of projecting missiles.

The invention of gunpowder, however at length, supplied a new and a tremendous power, which with the rapid and decisive agency which is so characteristic of all its effects, has banished every other mode of projection from the field and from the fortress. We shall make no delay in examining the questions which involve its early history in obscurity, nor even stop to consider who is to receive the honor of its first composition. Very soon after its introduction as a means of war, the nations of Europe who attempted to employ it, vied with each other in the magnitude of the pieces of artillery

which they brought into the field. They were usually made of bars of metal hooped together; some of very great size are described in books, many of which are now existing in the fortresses of Europe. There is one in Asia, probably the largest in existence. Fourteen feet long, nearly five in diameter, and two and a half bore.

The form and proportion of a piece of ordnance vary according to the object for which any particular piece is designed. The bore of the cannon is cylindrical excepting a cavity in large pieces, near the breech for the reception of the powder.

We shall enumerate some of the principal varieties of ordnance, with a short description of the particular purposes of each.

MODERN ORDNANCE.

1. *The cannon.* This name is applied to those pieces whose object is to throw a simple heavy ball, which is to do injury solely by its momentum. It is mounted in various ways, according to the particular purpose for which it is designed, to be placed in a fortress, or in a ship, or to be carried into the field. It is supported by its trunnions, which are two cylindrical projections, one on each side, and is aimed by elevating or depressing its breech by means of wedges, and sometimes by a screw. As has been before remarked, this species of artillery was formerly made immensely large, but experience has taught military men, that by reducing the size more is gained by the ease and the frequency of the discharges, than is lost by diminishing the balls. The size of the pieces has been consequently much reduced. Those now in use by the European powers throw balls whose weight is from one to fortytwo pounds; — each piece receiving its name from the weight of the ball which it is intended to discharge.

The balls themselves are generally of cast iron. Stones were formerly used, especially when very large pieces were to be loaded. Stones coated with lead have sometimes been employed. Balls heated in a furnace

are often discharged for the purpose of setting fire to the object which they strike. From this piece of ordnance there are discharged *canister shot*, by which is meant a quantity of small balls inclosed in a tin case, and *grape shot*, balls of the same kind bound up tightly in a canvass bag. These coverings are burst by the violence of the discharge, and the balls scattered in every direction are very destructive to the ranks of an enemy. There are also *chain shot* and *bar shot*, consisting of two balls connected by a bar or a chain, which are principally used for the purpose of disabling vessels, by cutting the rigging and splintering the masts and spars.

2. *Mortars*. This species of ordnance is designed to discharge bomb shells, which are hollow balls of iron filled with gunpowder, with a slow match attached to each, of such length as to explode soon after the bomb strikes. It is necessary, in order to insure that the explosion of the shell should take place while it is in the vicinity of the object which it is intended to injure, that it should be discharged *into the air*, so that falling *nearly perpendicularly*, it remains in the place where it strikes, until the slow match is exhausted. The construction is consequently very different from that of the cannon. Its form resembles that of the household utensil from which it takes its name. It is fixed nearly perpendicular, and is susceptible of very little motion. The distance to which the shell is to be thrown, is regulated by the quantity of powder used in the charge. Mortars are also employed in throwing carcasses, which, like shells are hollow balls of iron, but are filled with highly combustible, though not explosive substances, designed to set fire to the buildings or ships upon which they fall.

There is a third kind of shells, called from their inventor, *Shrapnells*. They are hollow balls of iron filled with small balls, and a quantity of powder, which is designed to explode when the shell has arrived at the point where it is intended to take effect.

In order that the reader may have some distinct conception of the nature and effects of these implements of death, we have selected from the journal of a British soldier in India, two extracts; one giving an account of the

effect of a breaching battery, that is, a battery of cannon, intended to make a breach in a wall, by which the enemy might enter, — and the other describing the effect of shells. They give the reader a pretty vivid picture of the nature of war.

‘ When the morning bestowed its bright rays abroad, we threw a little farther light upon the subject, by opening our breaching battery, accompanied with such terrific cheering and shouting, as seemed to startle the new risen sun, which at that identical moment appeared. The enemy, after a moment’s pause, were seen in a tremendous bustle, mustering their full force; and their heads were so thick, that, had our shelling battery been ready, we might have made dreadful havoc among the motley group. They shouted, yelled, screamed, groaned; small arms whistled, cannons roared; and, in an instant, the fort was enveloped in smoke. On the following morning, I went again on duty in the trenches. We retired into the wood before-mentioned, which had a path of communication with the trenches, though it was a considerable distance from the grand breaching battery. Our operations against the fort continued active and resolute; but our balls made but little impression upon the mud bastions and curtains. Many of them scarcely buried themselves, and others rolled down into the under works of the enemy, and were kindly sent back to us. It is almost folly to attempt to effect a practicable breach in a fort built of such materials. The crust you knock off the face of a bastion or curtain, forms a great barrier to your approach to a solid footing. Young engineers are too apt to judge, from the appearance of the fallen mud, that the breach is practicable; when, the first step the storming party takes, they find they sink up to their necks in light earth. A woful instance of this nature, I shall have to advert to more particularly in the course of my narrative; and, if it prove a timely hint to the inexperienced, I shall be rewarded. Stone forts are soon demolished; when undermined well at the bottom, the top will soon follow, and they cannot easily be repaired; but mud forts defy human power.

‘We this day erected howitzer and mortar batteries, and when they first opened, they struck terror and consternation into the enemy, who fled in every direction, to avoid those destructive engines; but, in a few hours, they dug holes in the ramparts, which they got into whenever they saw those unwelcome visitors on the wing; and, unless the shell happened actually to fall on them, they escaped in this way. But our shelling in those days was a mere bagatelle to what it is now. A shell in five minutes, was then enormous; now, twenty in one minute is by no means extraordinary, and these twice as big as in the times of which I speak.

‘This day the enemy was pretty passive; no doubt making places of refuge. Our shells, if thrown further into the town, must have been most destructive, for the population was evidently prodigious, from the number of fighting men. The houses frequently appeared on fire, and several small explosions took place daily; no doubt, small magazines. These little incidents generally created cheering by the besiegers, and redoubled firing by the enemy. In the course of the day we saw the Rajah for the first time: he was on the shabroodge, or royal bastions, with his suit, reconnoitering with a spy-glass. The officer commanding the howitzer battery laid a shell for the shabroodge, which struck the very top of it, and soon dislodged his highness and suite. In a moment, not a soul was to be seen.’

* * * * *

‘On the following day, after reconnoitering the fort and the ground in its vicinity, spots were fixed upon for new breaching and shelling batteries; and, in twentyfour hours afterward, we commenced our work of death on the fort and its obdurate inmates. Long ere the hour of the sun’s decline, it grew as dark as midnight. About ten o’clock, the terrific shelling commenced, every whistling shell bearing on its lighted wings messengers of death and desolation. I never saw these implements of destruction so accurately thrown,—some of them scarcely five inches above the walls of the fort. In five minutes the screams of the women in the fort were

dreadful. In a place so confined, where numberless houses were crowded together, every shell must have found its way to some poor wretch's dwelling, and, perhaps, torn from mother's bosoms their clinging babes. No person can estimate the dreadful carnage committed by shells, but those whose fate it has been to witness the effects of these messengers of death. On this occasion our shells were very numerous, and of enormous size, many of them thirteen inches and a half in calibre. The system of shelling had been so much improved in the twelve years which had elapsed since the siege of Bhurtpore, that, instead of about one shell in five minutes from a single battery, it was by no means extraordinary to see twenty in one minute, from the numerous batteries which were brought to bear upon this place. It was, at times, truly awful to see ten of these soaring in the air together, seemingly riding on the midnight breeze, and disturbing the slumbering clouds on their pillows of rest; all transporting to a destined spot the implements of havoc and desolation contained within their iron sides. The moon hid herself, in seeming pensiveness, behind a dense black cloud, as though reluctant to look on such a scene; and the feathered tribe, that were wont, in those warm nights of summer, to melodize the breeze, retired far into the distant woods, there to tune their notes of sorrow. Mortal language cannot array such a scene in its garb of blackest wo. Some carcasses were also thrown. These, when in the air, are not unlike a fiery man soaring above. They are sent to burn houses, or blow up magazines. Far and wide they stretch forth their claws of death; and well might the poor natives call them devils of the night or fiends of the clouds. To complete this dreadful scene, the roaring congreves ran along the bastion's top breaking legs and arms with their shaking tails. Nothing could be more grand to the eye, or more affecting to the sympathizing heart, than this horrid spectacle.'

This storming was successful, and the writer of the preceding account soon found his way into the fort, to witness the havoc which he and his comrades had made.

The description of the scene thus brought to view is too dreadful to be here described.

3. The third species of ordnance which we shall describe are *Howitzers*. They are intermediate in their construction between the cannon and the mortar, and are designed to combine, as far as they can be combined, the purposes of both. Like the mortar they are used for discharging the various kinds of shells, and they comprise a much greater extent of aim as they can be pointed at any angle of elevation. They are much more portable also. They can, in addition to this, be used like cannon for the discharge of solid balls. In fact, a shell is often discharged at a low elevation, so as to act at first by its impulse like a solid ball, and afterwards by its explosion.

4. The fourth species of ordnance is the *Carronade*, designed for throwing *cored* balls as they are called, — that is, hollow and empty. It is found that when a ball passes through a ship's side with great velocity, it makes a smooth and well defined hole. If on the other hand it passes with a *slow motion*, it tears and splinters the planks and beams in such a manner as to produce a much greater injury. To reduce the force then by which the ball would strike, by diminishing the weight, while the size remains the same, is the object gained by the carronade. It is much used in naval warfare.

We cannot here enter at all into a description of the endless variety in construction and use which *portable* fire-arms assume. For they do not differ at all in principle, whatever is the object for which they are designed, whether to become weapons of the infantry in the field of battle, or the means of health and recreation to the sportsman, or a protection to the traveller from the highwayman's attack, or the instrument by which the duellist may gratify his unhappy revenge.

The rifle, however, deserves a notice, both on account of the beauty of its theory, and the excellence of its practical operation. One of the greatest causes of error in aiming a common musket or fowling piece, is, that the ball generally receives, on leaving the piece, by unequal friction against the sides of the barrel, a rotatory mo-

tion which affects the course of the ball in a manner which depends on the direction in which this rotatory motion takes place. Now this will evidently depend on the side of the barrel on which the ball accidentally rubbed on issuing from the gun. It is for this reason that if a barrel is bent in any direction, the ball which issues from it, will, as it is said, be deflected in the contrary quarter. There will always be, from this cause, a deviation from a straight line, in the direction of the ball, as the axis of rotation will always be perpendicular to the axis of the gun.

In order to remedy this difficulty the idea was conceived of giving the ball a rotatory motion, whose axis should be *coincident* with the axis of the gun. This would prevent effectually any other rotation, while it would itself occasion no deflection. This object is accomplished by cutting spiral grooves on the interior of the barrel, which made one turn from the breech to the muzzle, so that the ball, in passing through the barrel, revolves once, on that axis which coincides with the axis of the barrel. It will of course continue in this state of revolution through its whole flight. In order that the ball should so adapt itself to the grooves of the gun, it must be driven down with considerable force. Its friction, consequently in passing out will be much greater, and to guard against the increased danger of bursting, which this will occasion, the barrel must be made thicker and stronger.

GUNNERY.

The nature of the motion of projected balls has been an object of very assiduous inquiry, especially by the nations of Europe, who have been ambitious of great military power. For many centuries the art of gunnery was founded entirely upon practice. The little deviation from a straight line which the path of the arrow or the spear presented, could be easily estimated after repeated trials, and an allowance sufficiently accurate for ordinary purposes, was easily made. And in regard to those great engines which the ancients constructed, in

which the course of the projectile was an arc of very considerable curvature, they were not in sufficiently constant and universal use to attract much attention to the nature of the motions to which they gave rise. Indeed, had this nature been well ascertained, the difficulty of accurately aiming machines of such construction, would have prevented the engineers of those days from deriving much practical benefit from the knowledge. In later days, however, when trains of artillery of great magnitude and variety, have become an essential part of the retinue of every army, and when the management of their operations have become one of the greatest objects of attention, as a means of attack and defence, at every battle, and at every siege, — military men and military governments have made great efforts to discover the true theory of the motions in question, taking into consideration *the resistance of the air*, which we neglected in the view of this subject, presented at the commencement of this tract. Courses of experiments, the most complete and the most accurate, have been made at great expense, especially under the direction of the governments of France and England. And the attention of the greatest mathematicians and mechanical philosophers, has been devoted to the problem which this subject presents. The result, however, has but partially rewarded these efforts. There are so many circumstances varying by complicated laws, affecting the phenomenon in question, that but little progress has been made, and after all the experiments and all the mathematics, a very large part of the iron and the lead is projected in vain. Galileo was one of the first who made any progress in examining the subject. He discovered from the nature of the two elements of the nature of a projectile, viz. the projectile force, and the force of gravity, that the course described by it must be a parabola, as shown already in this tract.

On instituting experiments, however, it was soon found that the fact differed widely from theory. The place upon which a ball fell after its discharge from a gun, especially where the velocity was great, was found to be very different from what it would have been, if the laws of the parabola had governed its movements. And this

inconsistency between hypothesis and observation was for a long time, a great perplexity to mathematicians and gunners. No one could dispute the demonstration, and it was still more difficult to deny the fact. It did indeed occur to some that the resistance of the air might have some influence upon the motion, while it was resolutely denied by the most weighty authorities that so rare and tenuous a substance could produce any sensible effect. One writer endeavors to remove the difficulty by supposing that a ball projected with great velocity, describes in the first part of its track, a *straight line* from the end of which the parabolic track commenced. During the straight part of its track the projectile force only could operate of course. This imagined straight line, the discoverer called *the line of the impulse of the fire*.

Some of Sir Isaac Newton's calculations on the subject of the resistance of fluids led him to suppose that the influence of the air was the true cause of the deviations from the parabolic path. This has been since ascertained to be the case. To determine, however, the law by which this influence acts, and the degree of deviation which it will in each particular case produce, is one of the most difficult problems in mathematics. The resistance varies with the velocity, increasing very rapidly as the velocity increases. Now this velocity is very irregularly varied, changing at every instant, and changing in a very different law, according to the angle of elevation at which it is thrown.

Many experiments have been instituted to determine many points of practical importance in regard to the construction and use of ordnance. The size and proportion of the parts of the several species; the quantity of powder which produces a maximum effect; the angle of elevation at which the range is greatest, and the proportion which the velocity of the ball bears to the quantity of powder, the length of the piece, and the nature of the ball. Various instruments have been contrived for the purpose of facilitating these inquiries, which it is unnecessary particularly to describe.

Neither mathematical calculation however, nor experiment have been able to ascertain with any great precision

the path of a projectile, through a resisting medium like the air. The practice of gunnery, therefore, depends almost entirely upon the skill which the gunner acquires by repeated trials. Some experiments have, however, given important and useful results. The following table presents the reader with the comparative effects produced by different charges, and different degrees of elevation. The ball used was of one pound weight.

Powder.	Elevation of Gun.	Velocity of Ball.	Range.	Time of Flight.
oz.		feet.		
2	15°	860	4100	9'
4	15°	1230	5100	12
8	15°	1640	6000	14½
12	15°	1680	6700	15½
2	45°	860	5100	21

By this table it appears that with two ounces of powder, the ball moved with a velocity of 860 feet per second, whereas with twelve ounces, which is six times as much powder, it moved only 1680, or about twice as fast. With the two ounces, its range, or the distance to which it went was 4100 feet, and with six times as much powder, only 6700, which is not nearly twice as far. The reason is, that with great velocities the resistance increases very rapidly. The resistance is as the square of the velocity, as it is mathematically expressed; that is, doubling the velocity, the resistance is increased fourfold; and three times the velocity, gives nine times the resistance. Indeed it can be proved that with a certain velocity, which can without much difficulty be given, a ball, will move on so fast that the air will not close over it instantly, but there will be a vacuum behind it. In this case the ball will be resisted at the rate of fifteen pounds to the square inch, which would make in a ball, four inches in diameter, *between 150 and 200 pounds*. Such a load as this must soon stop any ball; and it is found that whenever a ball is thrown with such a velocity, it almost instantly becomes retarded, until it is reduced to a much smaller velocity, so that the resistance will be less.

Various instruments have been devised for measuring

the incipient velocity of a cannon or musket ball, or the elastic force of various kinds of powder. We shall describe one, which is called the *eprouvette*. We must first, however, state that when gunpowder explodes, the expansive force is exerted *in every direction*. It acts not only against the ball, but against the sides and back of the gun. The force which it exerts each side is extinguished by the strength of the metal, but by the force exerted against the back or breech of the gun, the gun is thrown backward as much as the ball is thrown forward. We do not mean as *far* or as *swiftly*, but that the whole amount of motion is as great. That is, if the cannon or gun weighs one hundred pounds and the ball one, the cannon will be thrown back one hundredth part as far. This is called the recoil, and upon the well known mathematical principle that the action and reaction are equal, it is the same in amount as the motion of the ball.

The *eprouvette* measures the recoil. It is an instrument contrived for the purpose of comparing the strength of different kinds of gunpowder. It consists of a small brass gun, about two and a half feet long, suspended by a metallic stem or rod, turning by an axis on a firm and strong frame, by means of which the piece moves round in a circular arch. A little below the axis, the stem divides into two branches, reaching down to the gun, to which the lower ends of the branches are fixed, the one near the muzzle, the other near the breech of the piece. The upper end of the stem is firmly attached to the axis, which turns very freely by its extremities in the sockets of this supporting frame; by which means the gun and stem vibrate together in a vertical plane, with a very small degree of friction. The piece is charged with a small quantity of powder, (usually about two ounces,) without any ball, and then fired; by the force of the explosion the piece is made to recoil or vibrate, describing an arch or angle, which will be the greater or less, according to the quantity or strength of the powder.

To measure the quantity of recoil, and consequently the strength of the powder, a circular brazen or silvered arch of a convenient extent, and of a radius equal to its

distance below the axis, is fixed against the descending branches of the stem, and graduated into divisions, according to the purpose required to be answered by the machine.

The divisions in these scales are pointed out by an index, which is carried on the arch during the vibration, and then stopping there, shows the actual extent of the vibration.

Another contrivance which has been resorted to, to measure the force of a ball thrown by gunpowder, is called the Ballistic pendulum. It measures the force, not by the recoil, but by the force given to a heavy body suspended like a pendulum, and against which the ball is thrown.

‘The block of wood which is struck by the ball, instead of being left at liberty to move straight forward in the direction of the ball’s motion, is suspended like the weight of the vibrating pendulum of a clock, by a strong iron stem (with adequate braces,) having a horizontal axis at the top, on the ends of which it vibrates freely when struck by the ball. This large pendulum, after receiving the blow, is penetrated by the ball to a small depth, and by reason of the motion communicated, oscillates round its axis, describing an arch, which is greater or less according to the magnitude of the impulsion. From the extent of the arch described by the vibrating pendulum, the velocity of any point of the block can be readily computed.

‘Several blocks of this kind, varying in weight, from 600 pounds up to about twentyfive hundred pounds, were constructed and employed under the direction of Dr Hutton, for the purpose of ascertaining the initial velocities, as well as the velocities at different distances from the mouth of the piece, of balls weighing from one to sixteen pounds.’

We have thus presented to our readers the prominent facts in regard to this branch of human skill. The subject of war is at best a very melancholy one. It is never pleasant to consider the efforts which human ingenuity has made to facilitate the destruction of property and

life, and to arm passion and revenge, the usual animating spirit of war, with their deadliest power. We have not entered upon this subject for the purpose of awakening a military spirit — or cherishing a love of war, — but simply to give that degree of information which every general reader should possess, in order that he may understand the allusions with which all history is full.

It is sad to reflect how universally the history of nations is a history of war. Almost every page is a description of internal commotions or foreign struggles, in which we are continually presented with the dreadful spectacle of thousands meeting in the field, to mangle and to kill each other, by every means which ingenuity can invent, and expense obtain, and numbers almost countless, apply. From long habit we can read of these things with little emotion, — but how few of the readers of this tract, could actually see the bursting shell do its work upon a crowd of his fellow-men, — or behold a single individual shot down before his door, by a musket ball, without horror. But what is one shell, — or the shriek of one single victim of a musket ball, compared with the scenes to which every reader of history must be familiarized. It is better, however, if we are to look at these dreadful exhibitions of human guilt at all, that we should look at them understandingly; we can then better estimate their true character, — and more correctly judge of their nature and effects.

SCIENTIFIC TRACTS.

NUMBER XXIII.

RAIL-ROADS.

THE most simple inventions have been among the most important, though they soon became common and ceased to attract notice.

The cord and pulley must have caused an improvement upon mere brute force, as astonishing in its day as its multiplied action in spinning machinery has been surprising in our time; then it was that man could act where he was not.

The wheel itself now so simple, so component a part of daily action, was once an invention of no ordinary mind.

The cask or common hogshead was an immense stride in commercial facilities. By this, a man readily conveys over a level space, a ton weight, which would otherwise require twenty men to move, and on a slight inclination, he commands a self-acting power attainable in no other mode but by machinery.

In the history of locomotion there is much of this simple invention, less noticed than its value demands. If there is anything that distinguishes one people from another, it is, eminently, the power of intercommunication, and yet in principle how simple the means.

COMPARED WITH CANALS.

The knowledge and use of canals appear to have been of long standing. The ancients (though ignorant of locks,) were familiar with the simple canal or cut on one

level. In China, however, the canal from Canton to Peking with locks or inclined planes, is estimated to pass through 825 miles, and is supposed to have existed since the tenth century. A canal from the Nile to the Red Sea, connecting the eastern waters with the Mediterranean, was completed in the sixteenth century, after immense labor for many years; it was scarcely used, and being cut through a sandy country was soon obliterated. The Dutch have flourished for centuries beside their canals. In France the canal of Languedoc in 1680, and in England the Sauky canal from Manchester to Liverpool in 1755, appear to have been the first of importance in those distinguished countries.

In modern times the art of canalling has undergone but slight improvement, and with the exception of some alteration in locks, it appears to have started into a system almost at once.

There are two objections which exist against canals as a system. *First*, the necessity of a supply of water at the summit levels or highest points, and *second*, the nature of water as a resisting medium to bodies passing through it. The former cannot be obviated by any effort of science or invention, and canals, therefore, can only be located where a constant supply of water can be at command, on the highest levels. The second objection may be diminished, but only to a very limited extent, such as by the form of a boat, &c. The usual rate of a canal-boat for goods is but two to two and a half miles each hour, and for passengers three to four miles. On the Delaware and Chesapeake canal, passage boats have recently been propelled by an increased number of horses at six and eight miles, but from the motion produced in the water, and the consequent injury upon the canal, it is stated that the tolls of such boats will not repair the damage.

There is a third objection which attaches with peculiar force to this country. Canals in New England are rendered useless by ice often more than one third of the year. A rail-road on the contrary may at a small expense be kept in operation the whole of the year, except, occasionally, in the northeastern portion of the Union.

The Honesdale rail-road in Pennsylvania is kept open through the winter.

Notwithstanding such difficulties, however, the long and well tried utility of canals, their superior facilities for conveying heavy weights, which cannot readily be divided, the passing from one level to another at a trifling expense, will still give them honorable employment where they have been or may be readily constructed. Like an old and respected friend, they are not to be rudely passed, for a new and more fascinating acquaintance.

HISTORY.

It is a singular fact that the entire principle of the railway was introduced into England long before canals, if we except an unimportant cut of a mile or two made near Cambridge by the Romans.

In some of the principal collieries in the north of England, the use of the wooden rail for conveying coal carriages from the pit to the place of shipment, was adopted as far back as 1676, and possibly thirty or forty years prior to that time. It was not, however, till the celebrated joint stock year of 1825, that the subject excited much interest, when the projection of a railway from Manchester to Liverpool gave a new impulse, and the effects appear to be working a complete revolution in the business of locomotion.

The railway and its adaptation for a moving power, simple as it is in principle, is eminently a child of science and the arts. The improvements which have from time to time been adopted, and the inventions which have added continually to its merits, have been long and gradually overcoming the obstacles which this species of locomotion presented.

THE RAIL.

We are not informed that any other country has claimed with England the use of the railway until within a few years. At its early adoption in 1676, two continued wooden rails or strong pieces about four feet apart, were

laid on cross sleepers even with the ground. In process of time the rails were found more convenient, at a small elevation, clear from dirt and other accidental obstructions; and the renewing the rails when worn down, becoming inconvenient, the contrivance of a scantling or upper rail was adopted, and this being pinned upon the principal strong piece could be easily replaced. At this period wooden wheels were used, and the load conveyed was about two and a half times that on the ordinary roads. The inclination of the rail was graduated merely for this draft, which appeared to satisfy all the expectations of the period. After many years thin iron plates were placed upon the wooden scantling, wherever the friction became great from turnings or acclivities. Rail-roads continued much in this state until about 1776, when cast iron rails were introduced in the shape of the 'plate rail,' or tram rail-road, having the flange or rim upon the rail. All rails requiring the flange to be upon the wheel are called 'edge rails.' Cast iron wheels were first used with the iron rails, and it is only about thirty years since that stone supports became common instead of the wooden sleepers.

In 1790 the edge rail was invented, and this is now most approved. Square bars of wrought iron were tried about twentyfive years since with success; and iron rolled nearly into the form of the edge rail was also in use about ten years since.

From some extensive experiments made in England on the comparative strength of cast and wrought iron, the results were in favor of the latter. The greater vibration, however, is a serious objection.

The cast iron rails of certain length weighing fifty-seven pounds per yard required seven and a half tons to break them.

The wrought iron rails of same length weighing twentyeight pounds per yard required six and a half tons to overcome their permanent elasticity, and in this case there was a deflection or bend of one tenth of an inch in four feet. These rails were made for four tons on wheels, and it appears that the absolute strength of the rail should exceed the ordinary strain or load at least as three to one. The strongest wrought iron rails required are thirtyfive

pounds to the yard. It is found in the Liverpool and Manchester rail-road, that the very rapid succession of heavy carriages produces in consequence of a vibration, a much more destructive effect upon the rails than was anticipated. It is a singular fact, that the rolling motion upon the wrought iron rail prevents oxydation or rust. In Massachusetts it is proposed to substitute a running stone foundation of perfectly even surface, on which a thin rolled iron plate is to be laid about two and a half inches wide and half an inch thick; this plate is to be bolted down to the stone. The elasticity of this, being less than that of wood, renders it preferable, and the plan has already been partially adopted with success. The experience, however, at Manchester may suggest the propriety of greater thickness in the iron plate. To overcome the frost, so great an obstacle in our country to works of this description, it is proposed to lay deep foundations for the stone rail.

In a railway, the first principles are to form it throughout its whole length, as nearly upon a level and in as direct a line as *circumstances will permit*. This is obvious, for an acclivity for one hundred feet on a road of one hundred miles, would prevent a load over the whole extent greater than that limited by the ascent itself, unless at the cost of unloading or of extra power. This uniform level or gentle inclination is attained by deep cuttings through hills, by long embankments in the valleys, and by bridges over deep gullies and streams.

The width required for a public and double railway for extensive traffic, is seldom over twenty feet, and for a single track twelve feet, far less than that required for ordinary canals. The horse track is generally in the middle.

It is found that an ascent of twentysix feet in the mile makes no perceptible inconvenience in the railway, and that anything less than sixty or eighty feet produces but slight difficulty. In a canal on the contrary, four inches in the mile is the greatest allowance that can be made, even in feeding sections, absolute level being the rule. The Mississippi, at New Orleans even during the freshest falls but one and a half inches each mile. When it is

impracticable or inadvisable to construct the railway within the above limits, two or more such sections are connected by an inclined plane, and this united plan of travelling sections and inclined planes where stationary power is used may be continued over any obstacles and in any direction.

When the traffic is all one way as at coal mines, and the steep planes descending in that direction, the loaded carriages in their progress draw up those which are empty, by gravitation, and the planes are called self-acting. When the plane is ascending in the direction of the traffic an extra moving power is then required; and this is generally, from effect and economy, the steam engine. A continuous or endless chain is stretched over rollers, to one of which the engine power is communicated, and the carriages being hooked on to the chain are easily conveyed up or down. It is evident that several engines may act in succession on the same plane, and the planes are, therefore, sometimes a mile in length and may be repeated when requisite. There is also no limit to the angle of acclivity, except the inconvenience of preserving the load, and where the situation admits the carriages may even be raised perpendicularly.

At Quebec there is an inclined plane from the top of Cape Diamond to the St Lawrence, 500 feet long, and at an angle of fortyfive degrees. A steam engine at the bottom works an endless chain, and stone, cannon, &c, are readily conveyed on carriages at that angle. It was at first worked by horses at the top.

Of the power of the inclined plane there is no reasonable limit, where velocity is not an object. Thus merchant vessels are now drawn entirely out of the water in an hour or two, upon an inclined plane or marine railway, by a set of capstans, and ships of war, by a common steam engine, in the same time.

THE CARRIAGE.

The simple car upon four wooden wheels was at first the vehicle used upon the railway. This, being heavily laden, was slowly drawn by a horse. About the time

that iron rails were first used, the weight came to be divided into moderate loads upon several cars.

We shall only notice those in present use, the form of which varies according to the nature of the load. The four wheels are of cast iron and of one size, generally about three feet in diameter, but varying from eighteen inches to four feet. The rims of the wheels are now usually *case hardened*, by which the friction and wear are much reduced, and a true circular form more readily preserved. On the 'plate rail' the wheel is plain, but on the 'edge rail' a flange or rim is required on the inner side of each wheel to preserve the carriage in its track. The axle-trees are universally of wrought iron, the square ends being fixed into the wheels for steadiness, and the axles, therefore, revolve either on cast iron bearings upon the carriage, or on springs, or on a suspending chain, as the case may require. The weight usually placed upon one car, varies from one to four tons, and twenty or thirty, sometimes fifty of these cars are connected together, and drawn along by a simple moving power. The motion on a descending plane is regulated by a brake or friction lever, also called a 'convoy.'

MOVING POWER.

Dugald Stewart has remarked of printing, that in the fifteenth century, the wants of mankind were such that if Faust and others had not invented the art, somebody else would. So we may say of locomotion, in this century, that as the horse cannot satisfy the wants, in velocity, something of greater speed must be brought forward. From 1802 to 1806, appear the first effective experiments with the locomotive steam engine. It was not, however, supposed possible that the friction or adherence of the plain wheels of such carriages upon the rail, could be sufficient to allow any great weight to be drawn after them, and, therefore, the cumbersome appendage of cog wheels, and ratchet wheels, continuous and endless chains, propelling levers, &c, &c, continued to perplex the minds of engineers until about 1814, when it was first found

that the adhesion of the locomotive carriage with its plain cast iron wheels was adequate for every purpose on ordinary railways. The improvement consequent upon this, was effected by Mr Stephenson in the north of England, and until very recently, such engines with some unimportant alterations have been generally used where fuel is cheap. These locomotive carriages draw upwards of 100 tons on a level at four miles the hour, and on an average forty tons at six miles, performing the work of twelve to sixteen horses. The engines weigh from six to twelve tons and cost about \$1600.

The Liverpool and Manchester rail-road was originally intended for passengers principally. It is now completed, and 2500 passengers have been conveyed over it in a single day. It has four sets of tracks, two for rapid passage, and two for heavier burdens each way.

In October, 1829, a prize of £500 was awarded by the Directors of the work to the successful locomotive steam engine the 'Rocket.' The competition then called forth, issued in bringing before the world facts almost overwhelming in their nature and consequences.

The application of steam as a superior moving power upon a railway has been fully tested by these experiments, and the prize engine performed the required seventy miles. Another, the 'Novelty,' of beautiful structure and involving a new principle in the consumption of fuel, though not then successful, was much admired and has since caused various improvements in steam carriages. The cylinders of these engines were equal, and the pressure upon the pistons the same, the power therefore equal.

	Net weight.	Weight with fuel, &c.	Fuel for 35 miles.
Rocket	5 tons.	5 $\frac{3}{4}$ tons.	5 cwt. or 2 cents per mile.
Novelty	2 $\frac{1}{4}$ "	3 $\frac{1}{2}$ "	1 $\frac{1}{2}$ " $\frac{1}{2}$ " "

Actual performance on a course one and three fourth miles in length :

	Tons.	Miles.	Miles.
Rocket with 17	went	12 $\frac{1}{2}$ the hour, with passengers only,	24 the h.
Novelty with 15	"	20 $\frac{1}{4}$ "	32 to 35
"	35	13	

The Rocket performed seventy miles in six hours and two minutes, or over eleven and a half miles per hour, including stoppage. The distance from Liverpool to Manchester, thirtytwo miles, has been travelled over with passengers, in a little more than two hours.

The following among many data on this subject, have been ascertained from the laws of Natural Philosophy and from extensive courses of experiments.

1. That air as a resisting medium, (unless irregular in the shape of wind,) makes no perceptible difference at increased velocities on a railway.

2. That on a well constructed railway, the friction or resistance is that of the axle or a rubbing friction, and the slight adhesion of rolling upon the rail.

3. That the friction on a level is nearly as the weight, and the tractive force required, therefore, nearly the same at different velocities. From this we see that if weight is reasonably reduced, there is scarcely a limit to the locomotive power of steam, so long as the pistons can work and the wheels can turn.

4. That a horse exerts his greatest available power at two to two and a half miles the hour, and beyond this rate the horse requires the greater portion of his muscular action to propel *himself* forward, leaving but little for the load. At his customary rate seven eighths of his force is exerted upon himself, leaving one eighth only for the load. As the velocity increases, the proportion remaining for the load is of course diminished. In England every coach on the best roads that runs for twenty-four hours at nine miles per hour, drawing not over two tons, requires no less than 180 horses or ninety each way. Less than twelve horses would carry the same weight for the same time on the same roads at two and a half miles per hour.

A horse can, at a dead pull, walk off raising 5 to 600 pounds over a pulley, but the average of his tractive power when in regular employment, is not above seventyfive pounds.

The experiments of Leslie and others on this subject, give the following practical results applicable to rail-roads.

	lbs.	tons.
A horse at 2 m. exerts usually 112	draws on a level rail-road about 10	
3	75	6 $\frac{3}{4}$
4	60	5 $\frac{1}{2}$
5	45	4
6	37	3 $\frac{1}{2}$
8	28	2 $\frac{3}{4}$

The friction, therefore, of a ton upon a rail-road is about eleven and a half pounds. It has in recent practice been reduced to nine pounds.

On a rail-road the usual travel of a horse at two miles per hour, is about twenty miles per day, and his draft, therefore, equal to 200 tons for one mile, or the tractive power exerted one two hundredth part of the weight moved.

In this country we may estimate the ordinary travel or work of a horse at one third of a ton weight, or at two and a half miles per hour, on the best roads about two thirds of a ton weight, or one twelfth part of that on a rail-road. The draft or tractive force exerted on roads is equal to about one fourteenth part of the load.

5. In water the resistance is as the square of the velocity.

6. On a canal one horse at the most draws thirty tons at the rate of two miles per hour, and only one ton at six miles per hour. This rapid decrease of horse power on a canal compared with a railway, will appear more striking, thus :

	Miles.		Tons on a Canal.	Tons on a Railway.
One horse at	2	per hour draws	30	10
"	3	"	9	6 $\frac{3}{4}$
"	4	"	3 $\frac{1}{2}$	5 $\frac{1}{2}$
"	5	"	2	4
"	6	"	1	3 $\frac{1}{2}$
"	8	"	$\frac{1}{2}$	2 $\frac{3}{4}$

Tons.	Miles per hour.	On Canal.	Railway.
30	require at	2	1 horse.
"	"	3	3 horses.
"	"	4	4 $\frac{1}{2}$ "
"	"	5	6 "
"	"	6	7 $\frac{1}{2}$ "
"	"	8	9 "
"	"	86	11 "

At three and a half miles per hour the two are equal.

Steam-boats presenting less resistance, require less power, but the proportion, must from the nature of the water as a resisting medium, be the same.

Now, engines of twelve horse power, have for several years conveyed on a rail-road upon the average, forty tons at six miles per hour, that is, they have performed the work of forty horses on a canal, and twelve on a rail-road, and from recent experiments, locomotive engines have actually accomplished upwards of twenty miles in the hour with fifteen tons, or what (if it were possible,) would require 1000 horses on a canal.

It appears desirable that the plan of placing the horse upon a carriage to propel himself, and a number of loaded cars by machinery, is worthy of more attention, than it has yet received. The power of a locomotive engine is often greater than required. In descending the horse would rest, and proceed at a velocity much greater than his own. As the horse weighs but one third to one half a ton, this addition to the load would be trifling, compared with the seven eighths of his muscular power, which is required to propel himself when advancing on the ground. The great speed which is attainable by the locomotive engine, is also probably far beyond what will usually be required, when experience hereafter has made its deductions for liability to accident, and for these highways of commerce being covered with traffic.

It is worthy of remark, that stationary engines will probably be much superseded. The engine will be more frequently locomotive upon the carriage, working by a chain or otherwise, and additional horses will in other cases be furnished for the particular parts requiring increased power. This is frequently done at the hills in French roads.

EXPENSE OF CONSTRUCTION, &c.

The comparative expense of constructing a canal and rail-road, is about one third in favor of the latter.

In England, there are stated to be about 2600 miles of canal, in which thirtysix millions sterling are invested, or \$60,000 per mile. Six years since, more than 1500

miles of rail-road were in use, and 2000 more have been for some time projected. Of this 1500 miles, only about 100 are for general traffic, the greater part being in the coal districts. The Liverpool and Manchester rail-road cost from its very expensive cuttings, and the unusual number of tracks, \$90,000 per mile. The Stockton and Darlington cost \$45,000 per mile.

In our own country the

Erie Canal	cost per mile	\$20,000
Farmington Canal	do.	11,000
Blackstone Canal	do.	13,000
Hudson and Delaware Canal	do.	18,000
Boston to Springfield estimated at		13,000

Baltimore and Ohio Rail-road estimated	\$20,000 per mile.
Mauch Chunk	do. cost single 4,700
Ithica	do. 4,000
Lackawana	do. 6,500
Boston to Providence, to Albany, to Brattleboro'	
each estimated at	15,000

We must bear in mind, that the increase of distance by a canal is often one half beyond the length of the ordinary road. The rail-road on the contrary increases but little, and sometimes actually diminishes the route.

The Austrian rail-road cost \$10,000 per mile. This extends from Budweis on the Elbe eighty miles to Linz on the Danube, thus connecting the navigable waters of these two rivers, and opening an easy communication between the Black Sea and Hamburg. It was constructed in 1827 and 1828.

Near London, the annual expense of repairs on the great roads is often \$5,000 per mile. Some parts of our Cumberland road cost \$17,000 per mile, and part of the Lancaster turnpike in Pennsylvania cost \$15,000 per mile; neither of these are macadamized.

In Scotland, on a level, a single rail-road has been constructed, on which one horse draws ten and a half tons at four miles per hour, for \$3000 per mile. Here of course were no excavations or embankments.

The actual expense of rail-road conveyance on the most approved principles, must vary under different circumstances. Previous to the recent improvements in

England, the rail-road companies engaged to convey merchandize at one third the price, and in one third the time required on a canal. The late experiments conveyed at one farthing per ton for ten miles, or equal to round the globe for eight dollars per ton. The toll or railway tax, is not here included. In this country this toll has been estimated variously from one to three dollars per 100 miles each ton. In England rather more. This is but little more than coasting freight.

Rail-roads have also the advantage of being extended in single branches, at the moderate average expense of about \$3000 per mile, and thus villages and manufactories may be benefited, where a canal could not have extended its influence. The whole materials also of such a road and its branches might, if required, be taken up and carried upon itself to either end, and from thence conveyed to any distance, and be relaid where a change of circumstances might demand. A canal must of course be permanent.

It appears but a reasonable deduction from all these facts, that where rail-roads can with facility be constructed, they will by the aid of steam carriages gradually and permanently give a preference over canals.

RAIL-ROADS IN THE UNITED STATES.

The first work of this kind in the United States was at Quincy, in 1826. By this the granite is conveyed from the extensive quarries in that town, to navigable waters at Milton, a distance of two miles. This work is of the primitive kind and single. The rails are of pine, laid on cross sleepers with a scantling of oak on the top. On this scantling a thin rolled iron plate is placed, two and a half by half an inch, and secured by small bolts. From its being without a precedent in our country, the expense was great, and being too slight for the great weights conveyed over it, is not likely to be permanent; a part has already been relaid with granite rails.

In March, 1827, the railway of Mauch Chunk in Pennsylvania, was opened from the coal mines at that place to the Lehigh canal. This railway extends upon

an irregular inclination for nine miles, and was formed and laid down in the short space of sixty days. The loaded carriages descend the whole distance by gravitation, and when emptied are drawn up by animal power. The rate of descent is in some parts over twenty-five miles per hour.

The Honesdale rail-road from Lackawana to the Hudson and Delaware canal, continues seventeen miles, and thus connects the upper part of the same coal district, with the Hudson river and New-York. This was constructed in 1829, being also an edge rail of the primitive kind, and is temporary. It has five ascending planes, worked by stationary engines, and averaging half a mile each in length, surmounting in all a perpendicular height of 800 feet in three and a half miles. Towards the canal are three descending planes of nearly the same length.

In Pennsylvania, the route from Philadelphia to Pittsburgh, being 407 miles, partly by canals and partly by rail-roads, is in a state of great forwardness. First a rail-road to Columbia, eighty-five miles, thence a canal to the Alleghany mountains, thence a rail-road of forty miles across the mountains, thence a canal to Pittsburgh. This forms but a part of the internal improvements of this energetic and important state, which several years since had in hand 1230 miles of canals and rail-roads, at an expense of fifteen millions of dollars. The consequence is, that already the lands within reach of these works have increased in value, probably more than that amount. Goods were the first season thrust to Lackawana, some 120 miles into the forest, and then sold at little more than the retail prices of New-York and Philadelphia. The impulse thus given to agriculture and the settlement of the State may be conceived.

In Maryland, the Baltimore and Ohio railway is a stupendous undertaking. It will be 350 miles in length; the first 130 miles (between Baltimore and the Alleghany mountains,) will be passed with only one stationary engine. The magnificent and permanent style in which the work has been commenced, will render it expensive, but its advantages will doubtless be commensurate. A

part of this railway towards Baltimore is already opened for traffic.

From Augusta in Georgia, to Charleston, South Carolina, a railway is now in progress 100 miles in length.

A rail-road has even been projected to extend from New-York towards Missouri. A part of the distance has been already traversed, and the whole has been pronounced by the son of De Witt Clinton to be practicable, at an expense double that of the Erie canal, and but little more than that of the present London bridge. It is worthy of notice, that when the Erie canal was projected in 1809, Mr Jefferson said it *might* be finished in a century, and lived to acknowledge in 1826, that the age was nearly a century before him.

In New Jersey, a railway is now constructing across the State from Amboy bay, not far from New-York, to Camden, opposite Philadelphia; the distance is about sixty miles.

In Massachusetts, projected routes have been accurately surveyed, from Boston to Providence, fortytwo miles, to Brattleboro', 114 miles, to Albany, 200 miles, also to Lowell and Worcester. The two last only, have as yet been undertaken. In these several routes, (excepting to Brattleboro',) no stationary power is required, the ascent in no case exceeding eighty feet in a mile, or one foot in sixtyfive, this is an angle of less than one degree. Ascents in roads even where great traffic prevails, are sometimes ten degrees. The route to Albany rises to an elevation of 1440 above the Connecticut river.

A railway has also been projected from Brattleboro' on to Whitehall on Lake Champlain. A more eligible route, however, and one more likely to succeed, is that from Boston to Ogdensburg on the outlet of Lake Ontario. This would pass through Lowell, Concord, N. H., Montpelier, down the valley of Onion river and near Burlington; thence from Plattsburg on the opposite side of the lake to Ogdensburg. The whole extent is 350 miles, and though not accurately surveyed, has been ascertained to be practicable, requiring but three stationary engines, (as in seventeen miles at Lackawana,) and in no other instance having a greater ascent than fifty or sixty

feet in the mile. It would cross the Green mountains at the gulf, so called, the greatest elevation being about 1000 feet above the Connecticut. The importance of this, may be estimated from Ogdensburg, commanding a continued navigation for vessels of 120 tons, for 1200 miles along the lakes.

Besides the foregoing sketch, many hundreds of miles of rail-roads have been projected in different States, and some of the routes actually commenced, but an accurate notice of all cannot be expected here.*

* Just as these sheets were going to press, we met with the following vivid description of a scene upon the famous Liverpool and Manchester rail-road, which will give our readers a very clear conception of the pleasures, and the present dangers of this mode of travelling. It is contained in a letter from a correspondent of the New York Observer, and was published in that paper. We ought to remark, that the danger of such accidents, as the one here described, will be very much diminished as the art of constructing roads, and the engines which move upon them, advance towards perfection. — ED. SCI. TRACTS.

'I left Liverpool this morning, at seven o'clock, with a friend and fellow passenger of the ship, a very charming young man of Pawtucket, Mass., for London, via Manchester and Birmingham—the distance to London being 208 miles—by the railway to Manchester, of course. For who could pass by that?—I had walked up to the Liverpool end of the railway before, and saw that part of this stupendous and proud work. I had seen the trains of cars, both of passengers and those for transportation, come in and go out, led by the little, proud, quick, and spiteful engine—a truly sublime sight. No one, who has not witnessed the reality, can have an adequate idea of the scene. I have several times stood upon a bridge, thrown over the railway, about one mile from the place of stopping, and seen a train approach in the distance, rapidly nearing, and dart under me with such velocity, that when the engine had met the perpendicular line under my feet, with a train of cars behind of twenty rods in length, I have sprung with all possible agility to the opposite side of a bridge of twenty feet in breadth, and before I could reach it, the whole train had passed from under me, and seemed flying away to its goal—leaving the impression, that no power could possibly arrest its momentum, and that it must inevitably plunge into the town, be dashed against its walls, tearing everything away, which could be torn;—and yet the next moment, it is seen easing and easing away, and then at rest. I now speak of some views I have had today in the vicinity of Manchester, which were better than those I had at the other end.

The Liverpool end is in front of a hill of freestone rock, where

BENEFITS OF RAILWAYS TO OUR UNION.

The influence of such works upon the Atlantic, as well as upon the Western States of the Union, forces itself upon our consideration. The object of Virginia, Maryland, Pennsylvania, New-York and Massachusetts,

the cars are laden with passengers, and then drawn by a stationary engine through a dark tunnel of 300 to 400 feet, into a deep and rectangular basin, itself open to the heavens, but sunk about fifty feet in the same solid rock, topped and inclosed with artificial battlements of heavy masonry.

This immense artificial chasm is a beautiful, as well as a stupendous work. The deep cut in the rock continues, with gradual decrease, a large moiety of a mile. The basin above described is the starting and arriving point—or the goal. Here the locomotive engine is attached, and away it goes at the precise moment, and soon the passenger feels himself on wings. If he looks at the nearest objects, he is dizzy in an instant. He cannot endure it. And for relief, he throws out his eye upon the fields, and trees, and country around. The motion of the car, in its rapid flight, is so much like that of a coach running swiftly over smooth ground, itself being a close carriage, and the twitching so exactly similar to that of horses on a full jump, that in spite of the evidences to the contrary around me today, as I was whirled along, I several times imagined fully for a moment, that our horses were running to destruction with loose rein—and startled at the thought.

There are two separate trains for passengers, one of the first class, the other of the second—each making three trips a day to and fro. The first is a close carriage—or a train of coaches, each accommodating eighteen passengers in three separate apartments—running through a distance of thirtytwo miles, in one hour and thirty minutes. The second class is composed of open cars—runs through in two hours—fare three shillings and sixpence sterling. Fare for the first class five shillings. These trains often carry from 200 to 300 passengers. The average number of passengers per day, between Liverpool and Manchester, for the last two weeks, has been 2,200.

I started this morning in the first class, with six coaches in train, and about one hundred passengers. The first half way we passed in fine style, and high spirits, and having replenished the water for the engine, were soon under full speed again. I had frequently put my head out of the coach to look backward and forward, and abroad—to make such observations, as curiosity, and the novel interest of the scene, prompted. Sometimes a train, coming from the opposite direction, might be seen ahead, and soon it would brush by us, at a distance of three feet, with such velocity, that, pent up as we were, we could no more count the number of coaches, than the spokes in a woman's spinning wheel, when buzzing in its swiftest

is by these immense exertions, to bring the trade of the western regions over land, to the middle Atlantic shores, thus avoiding the circuitous and dangerous navigation attending the export of produce, even after it has reached New-Orleans, on the one hand, or the Saint Lawrence, on the other. Taking the line of Ohio and Indiana, as

turn. I speak as a matter of fact: not that we could not see them, but their speed added to ours, each going in opposite directions, rendered it absolutely impossible to count the coaches, as they passed our window. The rear presented itself almost the same instant with the front. All we could perceive was:—It is here, it is gone! Sometimes we ran fifteen miles the hour—sometimes twenty—and sometimes twentyfive. I should judge we were running at the rate of twentyfive miles—or more rather than less—when I looked out of the window forward, and instantly exclaimed, as my friend says, thrice, (though I do not myself recollect it,) “We are gone! we are gone! we are gone!” And surely I had good reason to make the inference. For at that instant I saw the engine deserting its proper track, and staggering and plunging headlong down the bank—reluctantly indeed, as if conscious of its charge and responsibility! And what could the train do but follow?—I had no sooner uttered these words, than—crash! crash! crash! went the whole train. And instantly the engine lay bottom upwards, directly abreast of our car, the fourth in our train, discharging its steam directly into our faces. By this time all was at rest, a heap of ruin. The tremendous crash, by which we were brought up, may in part be estimated, when it is considered, that although we were running at such a rate, we did not make a headway of more than two rods, after the engine plunged from the railroad. But you will be in pain to see us out of the steam. “Open the opposite door!” said I—“open the opposite door!” My friend, being nearest, made the attempt, but, not succeeding, jumped through the window. There were two ladies, a gentleman, and a boy, still remaining with me in the same apartment of the car. And how we all got out, I could not afterwards recollect. The escaping steam proved to come from the safety valve, and of course, gave us nothing more than a very—very hot bath. The forward car, next the engine, was drawn after it, and thrown over, with all its passengers. The next plunged into it, and stove its back in pieces. And each car run against its predecessor in the same manner, making more or less splinters, until all were brought up at rest, and began to disembogue their occupants, each actuated by the impulse of self-preservation. Soon, however, they began to help one another, and to look after the killed and wounded. After seeing my own apartment cleared of its tenants, I ran around in front of the circle—(for the wreck now made a circle,) and the first thing which attracted my attention, was the dragging out of the engineer, who lay buried under the engine—the machine having turned bottom upwards. The

something like a present centre to the Western States, Montreal and New-Orleans are about equally distant, and Baltimore, Philadelphia and New-York, are little more than half the distance of either. When, therefore, we have Ohio itself with a million of inhabitants *within* this limit, and consider the increased distance on the other hand, with a dangerous navigation beyond it, and the expense and unhealthiness of the great mart, New Orleans, we can admit, that these grand efforts of the Atlantic States, are not entirely visionary. To effect these purposes, no means have been presented, having the same facilities as rail-roads, and we may, therefore, suppose, that eventually, a large proportion of the natural and agricultural productions above Kentucky, may pass over to the Atlantic shores, and that the states thus interested, and the intermediate regions will be benefited in a proportion, at least, equal to the expense of these undertakings.

The operation of this inland commerce, as a common bond of union to the States concerned, cannot be too highly appreciated, or too much encouraged.

REFLECTIONS.

From an invention then, the principle of which is as simple as that of the chair we sit upon, the obstacles of time and space are overcome in a tenfold degree beyond

moment he was drawn out, he stood upon his feet, but his face and head frightfully disfigured with blood and dust. Some one immediately grasped his hand, and shook it very cordially, congratulating him for his life preserved. He was carried away, and I have not heard from him since, and therefore cannot tell how much he was injured. Through the exceeding mercy of God, no other person was hurt, worthy of notice, so far as I have learned. Two or three trains soon arrived from opposite directions, and were obliged to stop, as our wreck covered the whole way. Men, women, and children of the peasantry came pouring in from the adjoining farms, as they witnessed our misfortune. And by the help of all, we soon threw off from the ways our disabled cars—found three of them in a condition to be used in our necessities, although not sound—borrowed an engine, which happened along, and having packed in again, thick enough indeed, proceeded to Manchester, and arrived only two hours after the regular time.'

anything hitherto known. Places one hundred miles distant may, for every purpose of commerce, convenience and defence, be brought within ten, and those 1000 miles distant within one hundred.

An inland coasting trade we might, almost say, has arisen, which will carry home to our inhabitants their commerce, both in war and in peace, in winter and in summer, unparalyzed by adverse winds, by insurances or blockade; a means of transporting, in case of invasion, both troops and the munitions of war, from one portion to another of our country, with unexampled rapidity.

It is not the object of this treatise to defend the claims of railways. There is much conjecture about a matter so new, but that a portion of the anticipated results, will be an affair of pure history in some parts of our country, is about as certain as the rising of tomorrow's sun. Some twenty years since, Mr Stevens, one of the earliest and largest steam-boat proprietors in New-York asserted, that there were those then living, who would, between sun and sun, see New-York and Albany, (150 miles.) He was ridiculed at as visionary, but it has been done in ten hours.

The words of an accurate and practical engineer, who had long devoted his professional attention to rail-roads, are worthy of note. In recommending locomotive engines, he says; 'It is far from my wish, to promulgate to the world, that the ridiculous expectations, or rather professions of the enthusiastic speculatist, will be realized; and that we shall see them travelling at the rate of twelve, sixteen, eighteen or twenty miles an hour; nothing could do more harm towards their adoption or general improvement, than the promulgation of such nonsense.' In a future edition of his work, we shall probably see this passage amended, as the author, five years afterwards, was one of the judges at the late Manchester race, when the rate of thirtyfive miles, (and even fortyone for a short distance,) was accomplished.

SCIENTIFIC TRACTS.

NUMBER XXIV.

WHALE FISHERY.

[Continued.]

IN a former number, we described the ordinary process of attacking and capturing a whale. In continuation of the general subject, we proceed to devote the few pages of the present volume which remain, to a description of some particular incidents, which Scoresby narrates, and which farther illustrate the business, — and to an account of the manner, by which the oil is extracted.

INTERESTING INCIDENTS.

‘On the twentyfifth of June, 1812, one of the harpooners belonging to the *Resolution*, under my command, struck a whale by the edge of a small floe of ice. Assistance being promptly afforded, a second boat’s lines were attached to those of the fast-boat,* in a few minutes after the harpoon was discharged. The remainder of the boats proceeded to some distance, in the direction the fish seemed to have taken. In about a quarter of an hour, the fast-boat, to my surprise, again made a signal for lines. As the ship was then within five minutes’ sail, we instantly steered towards the boat, with the view of affording assistance, by means of a spare boat, we still retained on board. Before we reached the place, however, we observed four oars displayed in signal order,

* For a definition of these and other technical terms, see Tract, No. 17.

which, by their number, indicated a most urgent necessity for assistance. Two or three men were, at the same time, seated close by the stern, which was considerably elevated, for the purpose of keeping it down, — while the bow of the boat, by the force of the line, was drawn down to the level of the sea, — and the harpooner, by the friction of the line round the bollard, was enveloped in smoky obscurity. At length, when the ship was scarcely 100 yards distant, we perceived preparations for quitting the boat. The sailors' pea-jackets were cast upon the adjoining ice, — the oars were thrown down, — the crew leaped overboard, — the bow of the boat was buried in the water, — the stern rose perpendicular, and then majestically disappeared. The harpooner, having caused the end of the line to be fastened to the iron ring at the boat's stern, was the means of its loss; and a tongue of the ice, on which was a depth of several feet of water, kept the boat, by the pressure of the line against it, at such a considerable distance, as prevented the crew from leaping upon the floe. Some of them were, therefore, put to the necessity of swimming for their preservation, but all of them succeeded in scrambling upon the ice, and were taken aboard of the ship a few minutes afterwards. I may here observe, that it is an uncommon circumstance for a fish to take more than two boats' lines in such a situation; — none of our harpooners, therefore, had any scruple in leaving the fast-boat, never suspecting, after it had received the assistance of one boat, with six lines or upwards, that it would need any more.

Several ships being about us, there was a possibility that some persons might attack and make a prize of the whale, when it had so far escaped us, that we no longer retained any hold of it. We, therefore, set all the sail the ship could safely sustain, and worked through several narrow and intricate channels in the ice, in the direction I observed the fish had retreated. After a little time, it was descried by the people in the boats, at a considerable distance to the eastward; a general chase immediately commenced, and in the space of an hour three harpoons were struck. We now imagined the fish

was secure, but our expectations were premature. The whale resolutely pushed beneath a large floe, that had recently been broke to pieces by the swell, and soon drew all the lines out of the second fast-boat, the officer of which, not being able to get any assistance, tied the end of his line to a hummock of ice, and broke it.

‘ Soon afterwards, the other two boats, still fast, were dragged against the broken floe, when one of the harpoons drew out. The line of only one boat, therefore, remained fast to the fish, and with six or eight lines out, was dragged forward into the shattered floe with astonishing force. Pieces of ice, each of which was sufficiently large, to have answered the purpose of mooring a ship, were wheeled about by the strength of the whale; and such was the tension and elasticity of the line, that whenever it slipped clear of any mass of ice, after turning it round, into the space between any two adjoining pieces, the boat and its crew flew forward through the creek, with the velocity of an arrow, and never failed to launch several feet upon the first mass of ice it encountered.

‘ While we scoured the sea, around the broken floe with the ship, and while the ice was attempted in vain by the boats, the whale continued to press forward in an easterly direction toward the sea. At length, when fourteen lines, (about 1680 fathoms,) were drawn from the fourth fast-boat, a slight entanglement of the line, broke it at the stem. The fish again made its escape, taking along with it a boat and twentyeight lines. The united length of the lines was 6720 yards, or upwards of three and three fourths English miles; value, with the boat, above 150 pounds sterling.

‘ The obstruction of the sunken boat to the progress of the fish must have been immense, and that of the lines, likewise considerable, the weight of the lines alone being thirtyfive hundred weight.

‘ So long as the fourth fast-boat, through the medium of its lines, retained its hold of the fish, we searched the adjoining sea with the ship in vain; but, in a short time after the line was divided, we got sight of the object of pursuit, at the distance of near two miles to the eastward of the ice and boats, in the open sea.

One boat only with lines, and two empty boats were reserved by the ship. Having, however, fortunately fine weather, and a fresh breeze of wind, we immediately gave chase under all sail; though, it must be confessed, with the insignificant force by us, the distance of the fish, and the rapidity of its flight considered, we had but very small hopes of success. At length, after pursuing it five or six miles, being at least nine miles from the place where it was struck, we came up with it, and it seemed inclined to rest after its extraordinary exertions. The two dismantled, or empty boats having been furnished with two lines each, (a very inadequate supply,) they, together with the one in a good state of equipment, now made an attack upon the whale. One of the harpooners made a blunder, the fish saw the boat, took the alarm, and again fled. I now supposed it would be seen no more; nevertheless, we chased nearly a mile in the direction I imagined it had taken, and placed the boats, to the best of my judgment, in the most advantageous situations. In this case we were extremely fortunate. The fish rose near one of the boats, and was immediately harpooned. In a few minutes, two more harpoons entered its back, and lances were plied against it with vigor and success. Exhausted by its amazing exertions to escape, it yielded itself at length to its fate, received the piercing wounds of the lances without resistance, and finally died without a struggle. Thus terminated with success, an attack upon a whale, which exhibited the most uncommon determination to escape from its pursuers, seconded by the most amazing strength of any individual, whose capture I ever witnessed. After all, it may seem surprising that it was not a particularly large individual; the longest lamina of whalebone only measuring nine feet six inches, while those affording twelve feet bone are not uncommon. The quantity of line withdrawn from the different boats engaged in the capture, was singularly great. It amounted, altogether, to 10,440 yards, or nearly six English miles; of these, thirteen new lines lost, together with the sunken boat; the harpoon connecting them to the fish, having dropped out before the whale was killed.

After having taken a large circuit with the ship *Esk*,

in the open sea in search of whales, we saw two or three individuals, when at the distance of about twenty miles from the middle hook of the Foreland. The weather was fine, and no ice in sight. A boat was despatched towards one of the fish we saw, which was immediately struck. The men were already considerably fatigued, having been employed immediately before in a laborious work, but they of course, proceeded in the boats to the chase of the fast fish. It had made its appearance before they all had left the ship. Three boats then approached it, unluckily at the same moment. Each of them so incommoded the other, that no second harpoon could be struck. The fish then took the alarm, and ran off towards the east, at the rate of about four miles per hour; some of the boats gave chase, and others took hold of the fast-boat, and were towed by it to windward. When two boats, by greater exertions on the part of their crews, had got very near the fish, and the harpooners were expecting every moment to be able to strike it, it suddenly shifted its course under water, and in a few minutes discovered itself in a southerly direction, at least half a mile from any boat. It then completed a circuit round the fast-boat, with the sweep of nearly a mile as a radius, and though followed in its track by the boats, it dived before any of them got near it, and evaded them completely. When it appeared again, it was at least half a mile to windward of any of them, and then continued arduously advancing in the same direction. At various times during the pursuit, the boats having the most indefatigable crews, reached the fish within ten or fifteen yards, when apparently aware of their design, it immediately sunk and changed its course; so that it invariably made its next appearance in a quarter where no boats were near.

‘The most general course of the whale being towards the wind, it soon withdrew all the boats many miles from the ship, notwithstanding our utmost efforts, under a press of sail, to keep near them.

‘After six or seven hours’ pursuit, without success, the sky became overcast, and we were suddenly enveloped for some time in the obscurity of a thick fog. In

this interval the boats were all moored to the fast-boat, the men being fearful of being dispersed ; but on the disappearing of the fog, the pursuit was recommenced with renewed vigor. Still the harpooners were not able to succeed. They were now convinced of the necessity of using every measure to retard the flight of the fish. For this purpose, they slacked out nine lines, a weight in air of eleven hundred weight, while the crew of the fast-boat endeavored farther to retard his progress, by holding their oars firmly in the water, as if in the act of backing the boat astern. But this plan did not succeed. They then lashed two or three boats with their sides to the stern of the fast-boat, and these were dragged broad side first, with little diminished velocity for some time. But the fish at length, feeling the impediment, suddenly changed its course, and again disappointed the crews of two of the boats, which had got extremely near it.

Several times the harpooners seized their weapons, and were on the point of launching them at the fish, when in an instant it shot from them with singular velocity and disappeared. In this way the chase was continued for fourteen hours, when the fish turned again towards the wind. But the men were exhausted by such continued exertion, together with the hard labor to which they had been previously subjected, at the same time being without meat or drink, and sparingly sheltered from the inclemency of the weather.

By this time we had reached the boats with the ship. The wind had increased to a gale, and a considerable sea had arisen. We had no hope, therefore, of success. As, however, we could not possibly recover the lines at this time, stormy as the weather was, we applied a cask as a buoy to support them, and moored an empty boat having a jack flying in it, to the cask with the intention of keeping near it during the storm, and with the expectation of recovering our lines, and a faint hope likewise of gaining the fish after the termination of the gale. The boat was then abandoned. We made an attempt to keep near the boat with the ship, but the increasing force of the gale, drove us, in spite of every effort away.

On the first cessation of the storm, we made all sail towards the boat, succeeded in finding it, recovered boat and line, but lost the fish.

'On the twentyeighth of May, 1817, the Royal Bounty, of Leith, Captain Drysdale, fell in with a great number of whales in the latitude of $77^{\circ} 25'$ N., and longitude 5° or 6° E. Neither ice or land was in sight, nor was there supposed to be either one or the other, within fifty or sixty miles. A brisk breeze of wind prevailed, and the weather was clear. The boats were, therefore, manned and sent out in pursuit. After a chase of about five hours, the harpooner commanding a boat, who, with another in company, had rowed out of sight of the ship, struck one of the whales. This was about four o'clock in the morning, of the twentyninth.

'The captain supposing, from the long absence of the two most distant boats, that a fish had been struck, directed the course of the ship towards the place where he had last seen them, and about eight o'clock in the morning, he got in sight of a boat, which displayed the signal for being fast. Some time afterwards, he observed the other boat approach the fish, a second harpoon struck, and the usual signal displayed. As, however, the fish dragged the two boats away with considerable speed, it was mid-day before any assistance could reach them. Two more harpoons were then struck, but such was the vigor of the whale, that although it constantly dragged through the water from four to six boats, together with 16,000 fathoms of line, which it had drawn out of the different boats, yet it pursued its flight nearly as fast as a boat could row, and such was the terror it manifested on the approach of its enemies, that whenever a boat passed beyond its tail, it invariably dived. All their endeavors to lance it were, therefore, vain. The crews of the loose boats, being unable to keep pace with the fish, caught hold of and moored themselves to the fast-boats, and for some hours afterwards, *all hands* were constrained to sit in idle impatience, waiting for some relaxation in the speed of the whale. Its most general course had hitherto been to windward, but a favorable change taking place, enabled the ship, which had previously been

at a great distance, to join the boats at eight in the afternoon. They succeeded in taking one of the lines to the ship, which was made fast to the ship, with a view of retarding its flight. They then furled the top-gallant sails, and lowered the top-sails; but after supporting the ship a few minutes head to wind, the wither of the harpoon *upset*, or twisted aside, and the instrument was disengaged from its grasp. The whale immediately set off toward the windward with increased speed, and it required an interval of three hours before the ship could again approach it. Another line was then taken on board, which immediately broke. A fifth harpoon had previously been struck, to replace the one which was pulled out, but the line attached to it was soon afterwards cut. They then instituted various schemes for arresting the speed of the fish, which occupied their close attention nearly twelve hours. But its velocity was yet such, that the master, who had himself proceeded to the attack, was unable to approach sufficiently near to strike a harpoon. After a long chase, however, he succeeded in getting hold of one of the lines, which the fish dragged after it, and of fastening another line to it; the fish then turned fortunately towards the ship, which was at a considerable distance.

At four o'clock, in the afternoon of the thirtieth, thirtysix hours after the fish was struck, the ship again joined the boats; when, by a successful manœuvre, they secured two of the fast lines on board. The wind blowing a moderately brisk breeze, the top-gallant sails were taken in, the principal sails hauled up, but, notwithstanding the resistance a ship thus situated must offer, she was towed by the fish, directly towards the quarter from whence the wind blew with the velocity of a least one and half or two knots, during an hour and a half. And then, though the whale must have been greatly exhausted, it beat the water with its fins and tail in so tremendous a way, that the sea around was in a continual foam, and the most hardy of the sailors scarcely dared to approach it. At length, about eight o'clock in the afternoon, after forty hours of almost incessant, and for the most part fruitless exertions, this formidable and astonishingly vi-

gorous animal was killed. The capture and the flensing occupied fortyeight hours. The fish was eleven feet bone, (the length of the longest lamina of whale-bone,) and its produce filled fortyseven butts, or twentythree and a half ton casks with blubber.

‘Excepting when it has its young under its protection, the whale generally exhibits remarkable timidity of character.’

PROCEEDINGS AFTER A WHALE IS KILLED.

‘The first operation performed on a dead whale, is to secure it to a boat. The more difficult operation of freeing the whale from the entanglement of the lines is attempted. As the whale, when dead, always lies on its back, or on its side, the lines and harpoons are generally far under water. When they pass obliquely downward, they are hooked with a grapnel, pulled to the surface and cut. But when they hang perpendicularly, or cannot be seen, they are discovered by a process, called “sweeping a fish.” On one occasion, I was engaged in the capture of a fish, upon which, when to appearances dead, I leaped, cut holes in the fins, and was in the act of passing a rope through them, when the fish sunk beneath my feet. As soon as I observed this, I made a spring towards a boat at the distance of three or four yards from me, and caught hold of the gunwale. I was scarcely on board before the fish began to move forward, turned entirely over, reared its tail, and began to shake it with such prodigious violence, that it resounded through the air to the distance of two or three miles. After two or three minutes of this violent exercise, it ceased, rolled over upon its side, and died.

‘In the year 1816, a fish was to all appearance killed. The fins were partly lashed, the tail on the point of being secured, the lines, excepting one, were cut away, the fish lying meanwhile, as if dead. To the astonishment and alarm, however, of the sailors, it revived, began to move, and pressed forward in a convulsive agitation; soon after it sunk in the water to some depth, and then died. One line remained attached to it, by which it was drawn up

and secured. After a fish is properly secured, it is carried towards the ship. All the boats join themselves in a line, by ropes carried for the purpose, and unite their efforts in towing the fish towards the ship. The course of the ship is directed towards the fish, unless in calms, or where the ship is moored to the ice, at no great distance, or when the situation of the fish is inconvenient or inaccessible, when the ship is obliged to wait the approach of the fish. When the fish is secured to the ship, the operation of *flensing* is performed. For this a variety of knives and other instruments are requisite. The enormous weight of a whale prevents the possibility of raising it more than one fourth or fifth part out of the water.

PROCESS OF FLENSING, i. e. REMOVING THE BLUBBER.

‘Before the harpooners descend upon the fish their feet are furnished with spurs, to prevent their slipping. The blubber, in pieces of half a ton each, is received on deck, and being divided there into portable, cubical, or oblong pieces, containing near a solid foot of fat, and passed down between decks, when it is packed in a receptacle provided for it in the hold. As the fish is turned round, every part of the blubber becomes necessarily uppermost and is removed. When sharks are present, they generally help themselves very plentifully, during the progress of the flensing; but they often pay for their temerity with their lives. Fulmars, a species of bird of prey, pay close attendance in immense numbers. They seize fragments of the fish disengaged by the knife, while they are swimming in the water, but most of the other gulls, take their share on the wing. The burgomaster is decidedly the master of the feast; hence every bird is obliged to relinquish the most delicious morsel, when the burgomaster descends to claim it.

‘In flensing, the harpooners are annoyed by the surge, and repeatedly drenched in water, and are likewise subject to be wounded by the breaking of ropes, or hooks, or tackles, and even by strokes from each other’s knives. The harpooners not unfrequently fall into the fish’s

mouth, when it is exposed by the removal of a surface of blubber, where they might easily be drowned, but for prompt assistance.

'I was once witness of a circumstance, in which a harpooner was exposed to the most imminent risk of his life, by a very curious accident. The harpooner stood on one of the jaw bones of the fish, with a boat by his side. In this situation, while he was in the act of cutting away the carcass of the fish, a boy inadvertently struck the point of the boat-hook, by which he usually held the boat, through the ring of the harpooner's spur, and in the same act, seized the jaw bone of the fish with the same instruments, and thus, the poor harpooner was pinned to the fish. The carcass was disengaged, and began to sink. The harpooner threw himself towards the boat, but being entangled by the foot, he fell into the water. Providentially he caught hold of the boat with both hands, but being overpowered by the sinking mass, he was on the point of relinquishing his grasp, when some of his companions got hold of his hands, while others threw a rope round his body. The carcass of the fish was now suspended entirely by his body. He remained in this dreadful state, until means were adopted for drawing it back to the surface of the water.'

The process of extracting the oil from the blubber thus procured, is a simple one. The blubber, which is a sort of solid fat, is exposed in large boilers to the action of heat, and the oil is separated. Sometimes this is done on board the ships at sea, — at other times the blubber, previously cut into small pieces, is stowed in casks, and is brought home in this state, that it may be tried out more conveniently on shore.

The whale fishery is a very important branch of the business of this country. The chief towns from which it is carried on are Nantucket and New Bedford. There are in the former fifty manufactories of oil and candles. There are now sixtytwo ships belonging to the port, and six ships are building for the whaling business. The value of this fleet as fitted for sea amounts to about 2,000,000 dollars.

NOTICE TO THE READER.

The present number, it will be observed, completes the first volume of the Scientific Tracts. There was in the early part of the volume, one number containing thirtysix pages. To complete the number of pages, as was originally intended, we have made the two last numbers shorter than the others. We have added also a copious index of the subjects treated in the volume. The miscellaneous character of the work renders such an index highly necessary.

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