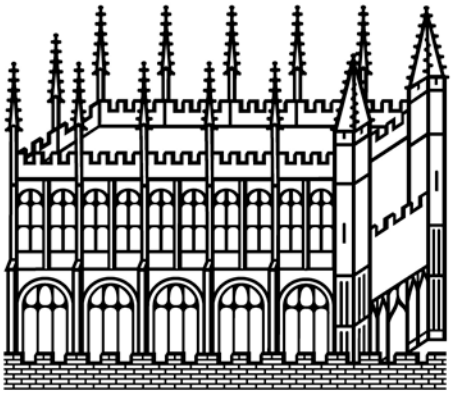

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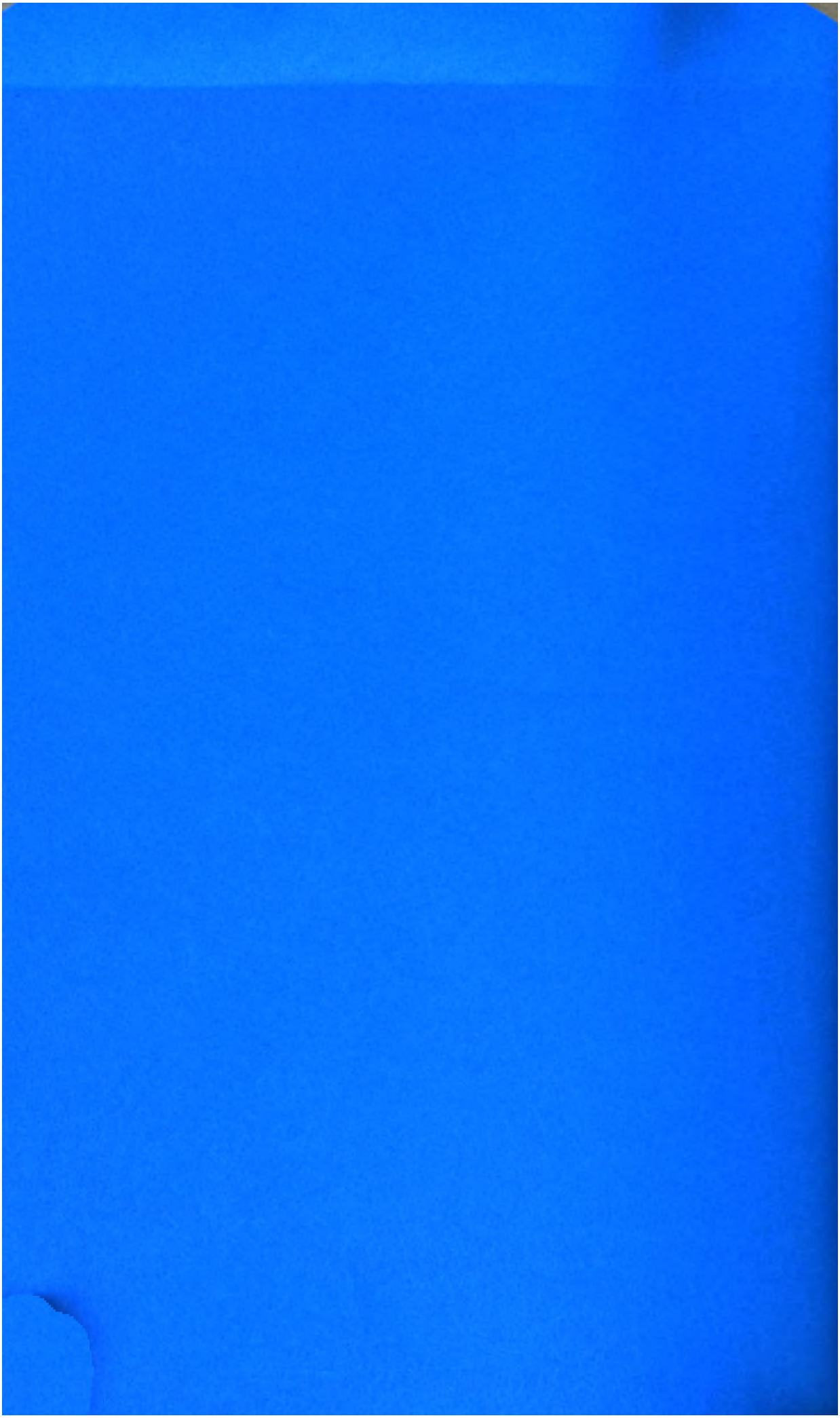

ELEMENTS

OF

MECHANICAL

AND

CHEMICAL

PHILOSOPHY.

BY

JOHN WEBSTER.

He hath made the Earth by his Power, he hath established the World by his Wisdom, and hath stretched out the Heaven by his Understanding.

JEREMIAH, 51 chap. ver. 15.

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PREFACE.

THE flattering reception of two former works, on the elementary principles of Chemistry and Natural Philosophy, induces the author to obtrude a third, which has in view, not only a general outline of the laws and operations of inorganic matter, but is particularly intended as a class book in the lecture room.

The entire sale of the former impressions makes the present publication more immediately necessary, as it faithfully delineates the outline of the subjects that are introduced at the lecture table, and generally in the order in which they are delivered. This arrangement must necessarily produce considerable advantage and great convenience to those who are animated by a love of natural knowledge, or feel any material interest in the subject of the lectures.

It is not to be expected that the few pages which this work contains, can give any extensive views of the subjects of *chemistry*, *mineralogy*, and *mechanics*, as well as the general history of these sciences; but it is still more than a mere syllabus, and will have its advantages accordingly.

The author feels a due degree of deference for

superior talents and a proper regard for prevalent theories; he has therefore been very sparing of his own opinions; it has been his exclusive object to condense what has already been received, and arrange it in a convenient order, with an anxious wish to promote the love of Natural Philosophy, by affording a plain and intelligent view of its leading features, that those who have not dedicated much time or attention to the elements of this science may not be deterred from the pursuit, or deprived of its general utility, either in promoting the temporal advantages of this life, or in developing brighter prospects of the future.

The noblest edifices of science ought to be regarded as only the threshold to the temple of the Deity. Natural religion is not sufficient for fallen man; but, like the helm which steers the majestic vessel through the trackless ocean to its destined shore, it guides us into the haven of faith, and introduces us to the consideration and reception of revealed truth. It shews us that we are surrounded by miracles in the natural world, as incontestable, and yet as inexplicable as those which sustain our belief in the interposition of God, by the revelation of his will.

It is thus that our minds are led to repose in the delightful conviction, that the God of nature is the same wise, merciful, and gracious Being that is revealed to us in the pages of inspired truth.

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INTRODUCTION.

AMONG all the various sciences that engage the attention of man, there is not one more particularly calculated to promote his general interest than that which is termed *Natural Philosophy*, or a knowledge of physical causes and effects.

The Deity is the first great inscrutable cause: he has established these secondary causes, which constitute the general laws of nature. The knowledge of these laws extend our views of his infinite power: it partially withdraws the veil that is spread over our senses, and manifests the beauty and wisdom of creation.

These pursuits of natural knowledge not only promote our eternal interests, but likewise conduce to our temporal advantages and rational pleasures.

Natural philosophy is the parent of the arts, and these form the basis of commerce.

Man in his primitive state is scarcely able to supply his own wants; but when he penetrates the works of the Creator, and applies the governing principles to his purposes, he gives facility to

his pursuits, relieves his own necessities, and contributes to the wants of others.

In an enlightened country like Great Britain, which, under heaven, owes to its commerce, arts, and sciences, the high and dignified situation that it possesses in the eyes of the world, little need be said to recommend the study of nature; our temporal and eternal interests are so conspicuously engaged, that every rational mind seems eager for the pursuit.

All the remains of history and of science, justify us in supposing that the present state of natural knowledge is more extensive than at any other period of human existence. This must be a very satisfactory consideration for those who are animated with a love of nature and seek the attributes of the Deity through the medium of his works; but much remains to be done,—we still see through a glass darkly; and although man in his present state of existence may be too low in the scale of intelligence to penetrate into the depths of nature's laws, and sufficiently appreciate the power and design of the first cause: yet he can learn enough to determine that it is the work of a Being infinitely more wise and intelligent than he is; and that it is a duty which he owes to God and himself to render these works both pleasing and profitable.

MECHANICAL

AND

CHEMICAL

PHILOSOPHY.

THE general operations of nature may be reduced to *three* heads.

First.—Those which are purely mechanical, in which matter and motion are exclusively concerned.

Second.—The chemical combinations which take place among the particles of inorganic bodies.

Third.—The chemical effects of organic matter: or the products of animal and vegetable life.

The laws which govern the planetary system in their diurnal and annual motion, and the general affection of masses of matter upon the surface of the earth, are referable to the first class.

Previous to the consolidation of the earth, the Almighty *fiat* impressed upon matter the principle of ATTRACTION, and under its influence the particles of the chaotic mass which then existed, began to aggregate and condense into a globular body of determined magnitude.

We are still unacquainted with the principle of attraction: but its laws are well understood, and its effects are constantly visible. The same power that consolidated the sphere which we inhabit, forms a drop of water, or combines the dispersed globules of quicksilver, and the force is according to the quantity of matter: so that bodies on or near the surface of the earth are governed by its superior influence.

If no other principle operated upon matter except the power of attraction, the earth would have been a homogeneous solid, of uniform density at equal distances from its centre: but to effect the views of the great Creator in the phœnomena of nature, matter became modified by the influence of heat.

CALORIC, or the matter of heat, is an imponderable element, repulsive among its own particles, which is universally diffused throughout the

earth; and as different bodies, under certain circumstances, are endowed with various capacities for specific or latent heat, this repulsive element is constantly opposed to the power of attraction; consequently, the influence of the latter, or that power by which the particles of bodies tend towards each other, is overcome by the repulsive agency of caloric, according to the disposition of the body for this element. Thus the number of particles that are contained in the same bulk, or the specific gravity of a body, depends on its capacity for latent or specific heat: so that matter becomes modified by this influence, and hence arises the different specific gravities which bodies possess.

The inorganic matter that composes the earth being thus acted upon by the power of ATTRACTION and CALORIC, becomes the temporary abode of man, to prepare himself for the eternal presence of his Creator. Inferior animals supply his necessities, and the earth teems with vegetable life, admirably adapted for their support, and to serve as a connecting link in the great chain of nature, by converting inorganic matter into living substance.

HEAT, LIGHT, AND ELECTRICITY.

THESE are apparently the first principles that are employed in the economy of nature. They give and preserve life in the animal and vegetable world, and produce all the changes and properties amongst the particles of inorganic matter.

The influence of HEAT rouses all the dormant energies of the vegetable creation, and brings forth the fruits of the earth in their due season. All nature languishes without the vivifying influence of solar rays, and under a certain privation of heat, both animals and vegetables perish.

LIGHT is not less essential than heat in supporting the vital principle. The generality of animals could not exist without the influence of light; and such is the avidity of vegetables for this element, that they turn their tender flowers, or present their leaves to obtain the cheering influence of the sun, and become sickly and etiolated as they are deprived of it. Even inorganic bodies absorb and give out light in a passive state; and it is very sensibly produced in many chemical changes.

ELECTRICITY seems to possess the united properties of light and heat; and like these bodies

it is universally diffused throughout every substance in nature, and is capable of existing in a combined and active state.

The universal distribution of this fluid would be a sufficient argument for inferring its great importance, if its visible effects were wanting, in the economy of nature. The valuable discoveries that have recently been made in the science of electricity, shew the great influence which it possesses in the *animal, vegetable,* and *mineral world.*

All *animals* possess an electrical capacity, and some have the power of communicating or discharging their electricity in such quantities as to produce a strong muscular irritation upon those that receive its influence.

The electric fluid may be obtained from animals generally, by excitation, or friction; and more particularly from those that are covered with hair, or fur, on account of the non-conducting power of these substances.

The great advantages which are daily derived from the influence of electricity, in a variety of diseases, sufficiently indicate its importance in the animal system.

The electric fluid is found to promote the evaporation of fluids generally, and impels them through capillary tubes. It likewise increases the circulation of the blood, and promotes insensible perspiration; and as the animal fluids are

conductors of electricity, it is constantly disseminated through the body from its general receptacle, the earth.

The importance of electricity in promoting the growth of *vegetables*, has been fully proved many years ago. If two plants of the same growth and species be placed near each other, and one of them be electrified daily, it has been found that the electrified plant will vegetate faster, and with more strength and energy than the other.

Vegetable fluids are good conductors of electricity, and become the means of transmitting it through the vegetable body, from the earth to the atmosphere, or from the atmosphere to the earth. In the first case, the fibres of the roots receive it from the earth; in the second, the ramifications of the branches and the points of the leaves collect it from the atmosphere.

In the *mineral* department of nature, the influence of electricity is not less conspicuous than in the animal and vegetable creation.

All bodies are endued with an electrical capacity, which varies under every change of composition; so that different bodies possess different electrical capacities.

Sir H. Davy has shewn that *all chemical affinity is the result of electrical influence*, or, that the chemical combination or force with which the particles of particular bodies combine, depends upon the opposite electrical states of these bodies;

even the character and properties of bodies change, as they change their capacity for electricity.

Thus, on account of the important agency of these imponderable elements, *Heat*, *Light*, and *Electricity*, it seems consonant with a general view of the laws and operations of nature, to commence the subject with the present theory of these elements.

Although our senses assure us of the existence of Heat, Light, and Electricity, yet the greatest possible quantity of any one of these elements, that can be collected, is not found to possess the least weight, even in the finest scale. This, however, argues nothing against their actual existence as bodies; it only shews matter in a highly rarified state. A piece of musk, and many other odorous bodies, may be accurately weighed, and left in a room for years, in which it will constantly affect our sense of smell; yet, notwithstanding this perpetual evolution of matter, it is found to have lost no sensible portion of its weight.

The particles of Heat, Light, and Electricity, are acted upon by the influence of attraction, in common with the particles of the grossest bodies; and we can imagine, that if these particles were aggregated and consolidated, in sufficient quantity, they would become sensible to our touch.

Heat, Light, and Electricity appear to have great relation to each other. Heat is diffused,

Light is absorbed, and Electricity resides in every mass that composes our earth: they are equally imponderable, and different bodies have different capacities for each of them. It is an invariable law of nature, that when bodies change their capacity for electricity, they change their capacity for heat. Heat, Light, and Electricity, are equally essential, both to animal and vegetable life. Solar or culinary heat will set fire to inflammable bodies and oxidize metals: the influence of electricity will produce similar effects. And solar and electrical light are both refrangible and decomposable.

Although the analogies among these three important elements of nature are peculiarly striking; yet we are still unable to comprehend their first principles. From the great similarity between the effects of electricity and the united effects of light and heat, we might be led to suppose that heat and light are emitted from the sun, in an independent state; and by some means, totally unknown to us, they combine on reaching the earth, and constitute electricity; each element still retaining its primitive agency.

ELECTRICAL ACTION.

THERE have been various opinions proposed at different times, to account for electrical action, or the sensible effects of electricity; but that which seems the most probable and most prevalent, is founded upon the Franklinean theory of positive and negative electricity. It supposes that when the electric fluid is equally disseminated throughout every part of a body, there can be no electrical action: but if by any means the uniform quantity is disturbed, and a greater accumulation is made in one part than another; by the general law of equilibrium, the accumulated fluid will constantly endeavour to rush to that part where it is deficient, to restore an equality throughout the body. The accumulated state of electricity is called *plus*, or *positive electricity*; the diminished quantity, *minus*, or *negative electricity*.

If a glass jar be coated inside and out with tin foil, to about two inches from the top, and a knob and wire be connected with the interior; on presenting the knob to the prime conductor of the electrical machine, the electrical fluid will accumulate on the interior

surface of the glass, by means of the conducting power of the metal which is in contact with it; and the electricity which resides on the exterior surface of the glass will escape through the metallic coating in the same proportion that it accumulates in the interior.

In this situation the electrical fluid is said to be in an acting state: inasmuch as the electrical equilibrium of the jar is destroyed; but an immediate discharge, or an instantaneous restoration will take place as soon as any metallic, or conducting circuit is formed between the exterior and interior surfaces of the jar.

The bottle form is not absolutely necessary in this experiment. Glass plates were used for this purpose, long before jars were employed; but as bottles or jars offer the largest surface, and the greatest convenience in the smallest space, they are generally preferred.

If the jar be placed upon an insulating stand, or upon a plate, supported by a glass pillar, it will not charge, because the electricity cannot escape from the exterior to the earth, on account of the non-conducting power of the glass pillar: but if the finger, or any conductor of electricity, be presented to the outside of the jar, the electric fluid will pass from the conductor, and an accumulation will take place in the interior, according to the quantity carried off from the exterior.

If two small jars be positively charged, or have an accumulation of electricity in the interior, and a communication be made with the exterior surfaces, by a chain or wire, on bringing the knobs together, no explosion will take place; but if the knob of one jar be presented to the side of the other, it produces an electrical discharge.

If the accumulation be made on the exterior, and the fluid be negative or deficient in the interior, similar effects will be produced: but if the accumulation be made in the inside of one, and on the outside of the other; when the knobs communicate, an explosion is produced. These experiments serve to shew that no electrical action can take place where there is an electrical equilibrium, and that all electrical effects depend on opposite states of electricity.

If two jars of different capacities be connected, the electricity may be conducted from one to the other, in such a manner as to produce four or five distinct explosions, before an electrical equilibrium is obtained.

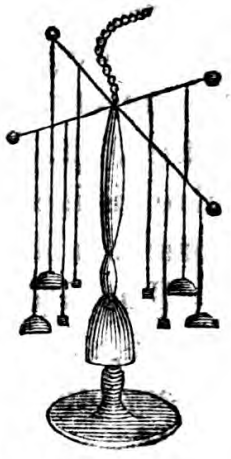
The electrical fluid, like caloric, is repellent amongst its own particles; but is attracted by every other body.

If a piece of light downy feather, or cotton wool, be held at the distance of a foot from an electrified conductor, it will be attracted by it, and afterwards repelled: for the electric atmos-

phere which surrounds the prime conductor attracts the body, until it becomes electrified with a portion of the same fluid; after which, the atmosphere of the conductor and that of the feather repel each other, and the latter is driven off till it has discharged the accumulated quantity, then it returns again on the same principle as before.

Paper figures may be made to dance between two brass plates, by suspending one from the prime conductor, and supporting the other by a metallic stand.

The electrified bells afford another pleasing illustration of electrical attraction and repulsion.



Four small bells are suspended by chains from four stiff wires, and from the middle of each arm a small clapper is hung by a silken string; the upper part of the stand that supports the bells is made of glass, and at the lower end another bell is fixed, which communicates with the earth. When this apparatus is placed near the prime conductor, the small insulated bells become electrified, and attract the clappers which are suspended near them: these positive atmospheres

now repel each other, and the clappers are driven off and become attracted by the uninsulated bell in the centre, where they deliver their electricity, and return again, which keeps the bells constantly ringing.

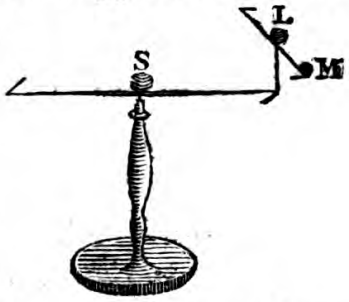
If a cork ball be suspended by a thread between two jars, one of them only being charged with electricity, the knob of the charged jar will attract the cork, and it will be immediately driven off to the knob of the uncharged jar; thus it becomes a carrier of electricity between the two jars, until an electrical equilibrium is produced.

Points receive and deliver the electrical fluid with much more facility than knobs. If a knob be held near the conductor of an electrical machine, the electric sparks will be seen darting towards it: but if a needle or fine pointed metallic wire be presented to the conductor, at three times the distance of the knob, the sparks will instantly cease, and the electric fluid will be silently carried off by the point.

If the point is attached to the conductor, a brush of electric light is seen issuing from it in a darkened room; but when the point is presented to the conductor, a small globular spark appears at the end of it, which shews, that, in the first instance, the electric fluid is given out from the point; in the second, that it is received by it.

The electric orrery has its revolution from the influence of points.

A piece of bent wire is suspended by a needle in the top of a glass stand, and a small globe of glass is fixed in the centre. At one end of the wire is another needle, which supports a short cross wire bent at each end. L. is a pith ball placed upon it, representing the earth. M. is a smaller one at the end, which represents the moon; and the small glass globe, S. the sun. When the conducting chain is connected with the needle at the top of the stand, and the electrical machine is put in motion, the sun turns round on its own axis, and the moon makes her revolution round the earth, whilst the earth is carried in its annual orbit round the sun.



One of the great objects of science is to add to the benefits of society; how much then are we indebted to Dr. Franklin for his great electrical discovery of the identity of lightning and the electric fluid, by which he was led to the formation of *conductors* for preserving buildings from the tremendous effects of lightning.

Those bodies are called conductors, which convey the electrical fluid with the greatest facility. Metals hold the first rank, then charcoal, water, acids, and animal and vegetable fluids.

Those bodies that restrain the transmission of the electric fluid, are called non-conductors; of

this description are glass, resin, wax, hair, paper, and silk.

The experiment of Dr. Franklin, made with a silk kite and wired string, shewed that the electrical fluid is diffused through the atmosphere as well as the earth, and that the clouds possess unequal quantities; or retain a positive and negative state with respect to each other; and that the general effects of meteorology are dependent upon electrical action.

We are perfectly aware, from observation and experiment, that electric changes are perpetually taking place; but it only occasionally happens, that the electrical intensity is such as to produce a sensible discharge, or render the effects of the electrical fluid visible: this is called lightning.

The destructive effects of the electric fluid, in the character of lightning, take place when the electric state of the cloud is induced by a contiguous portion of the earth's surface in an opposite state. The electric fluid, in this case, seizes upon any intervening conductor that it meets with in its passage from one state to the other; and if the body possess sufficient conducting capacity, an electrical equilibrium obtains without any destructive consequences; but from the elevated form of trees, church spires, chimney tops, and even the animal body, the electric fluid in its transmission frequently seizes these objects; and

from their non-conducting capacity, arises all those disastrous effects that mark its circuit.

When Franklin discovered that the electric fluid and lightning were the same, and that metals conducted electricity with perfect facility, he applied metallic rods to the most elevated part of buildings, that the electric fluid of the atmosphere might be carried harmlessly to the earth.

The universality of these conductors sufficiently prove their utility: we are satisfied of their importance in this country; but it is in tropical climes, where electrical convulsions are much more frequent and tremendous, that this simple instrument is truly estimated in preserving the lives and property of our fellow-creatures.

The following experiment may serve to shew the advantage of metallic conductors, and the necessity of keeping them in good repair.

Let A D represent the end of a house, and A G H D an uninterrupted conductor carrying off the electric fluid of the cloud, or jar, E, to the earth. If the square piece of wood, G B C H be reversed, so as to break the conducting circuit, and interrupt the electric fluid in its passage, the piece of wood, which may be considered as a

portion of the building, is driven out with considerable force.

There were very different opinions, for some time after this important discovery, respecting the form of the conductor. Some persons recommended a knob at the upper extremity; others, a point: but the evidence of facts has long ascertained that pointed conductors afford the greatest security.

This conductor may be formed of an iron rod, not less than half an inch in diameter, fixed near to the most elevated part of the building; the upper extremity rising about five or six feet above the top, and the lower perforating the earth two or three feet, taking care to turn the lower extremity outwards.

Although the influence of points extends much further than knobs, and conveys the electric fluid silently, either from the earth to the passing cloud, or from the cloud to the earth; yet, when the building is very large, for more perfect security, it is desirable to place a conductor at each end, being careful to keep the upper extremities quite sharp. A good conductor is made by screwing three brass points into the top of an iron rod, about half an inch in diameter: the brass wires preserve their points, and the iron conductor answers the purpose of a brass one, at a much less expense.

The *electric spark*, in a darkened room, produces

a number of pleasing experiments, which are more calculated to entertain than instruct. The arrangement is usually made by pieces of tin foil, laid upon the surface of glass, at a very small distance from each other: the foil serves as a conductor for the electrical fluid, and at each break, a bright spark appears. By making these interruptions in a proper direction, very brilliant words and figures are produced.

When a great accumulation of the electric fluid is required, the *electric battery* is employed. This is composed of a number of jars, contained in a box, the bottom of which is lined with tin foil, to connect the exteriors; the interior communication is made with wires and knobs, passing from one jar to another.

When the battery is to be charged, a communication is made by a chain or wire, from the prime conductor to the interior of the battery, and the electric fluid equally accumulates in each jar; when it is discharged, a conducting circuit is made between the interior and exterior of the battery. This apparatus affords an electric power, according to the quantity of surface employed; but in principle, it does not vary from a single jar.

The battery affords us an interesting view of the influence of electricity, by exhibiting its effects in setting fire to inflammable bodies; penetrating bad conductors; reviving some metals

from their oxides, and burning others; decomposing water, and many other bodies.

The prodigious velocity of the electric fluid, and its power of igniting inflammable bodies, may be shewn in the following manner: Place some resined cotton wool between two pair of metallic balls, and fix them against the side of a room, about twenty feet asunder: let a wire communication be made between the battery and the balls; and when the former is discharged, the electric fluid will rush through the conductor, and at the same moment of time, the inflammable substances will be seen blazing at each extremity of the room.

A small portion of gunpowder confined in the model of a house, may be set on fire by the electric spark, and the building blown up.

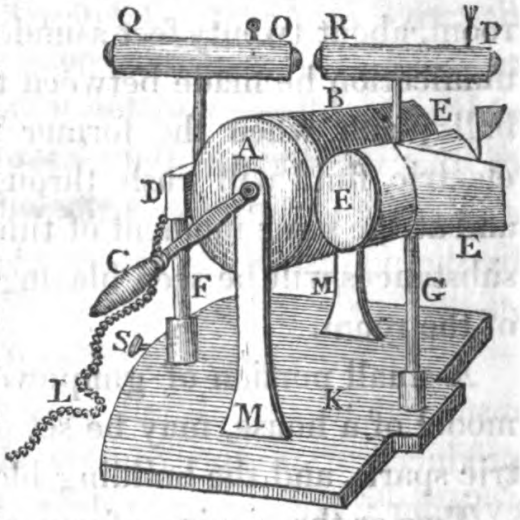
Two or three quires of paper may be perforated by the discharge of the electric battery.

If a little vermilion, or oxide of quicksilver, be smeared on a card, the metal will be revived by passing a strong electric discharge over it.

Or, if gold or silver leaf be placed between two white cards, by making the leaf a part of the electric circuit, the small quantity of conducting matter which it contains, will not afford sufficient facility to transmit the electric fluid from the battery; by which means the metal becomes burnt or oxidized, and indelibly incorporated with the surface of the cards. By a proper

arrangement, flowers or figures of various kinds may be produced in this way from the oxides of different metals.

Electrical machines are of various constructions; the cylindrical is the most common, and in some cases the most useful; particularly where a negative electricity is required.



A, in the figure, represents a glass cylinder, the axis of which is supported by the two sides, M M, and these are fixed into K, the basis of the machine. C is the handle by which the cylinder is turned, and D, the cushion, or rubber, which is supported and insulated by the glass pillar, F. The lower end of F passes into a socket that is acted upon by the screw S, for the purpose of increasing or diminishing the pressure of the cushion on the surface of the cylinder. B, is a piece of black silk, which prevents the electric fluid from flying off, and reaches nearly to the receiving points fixed in the prime conductor, E E; and this conductor is supported by the insulating pillar of glass, G; so that the electrical fluid which is collected on it cannot escape, but accumulates for the purpose of experiment.

A small quadrant electrometer fixed into a hole in the conductor, shews the increase or decrease of the electrical fluid, by the rising or falling of the index. The chain, L, has one end fastened to the cushion, and the other lies upon the table or floor, to conduct the electric fluid.

Those who favour the system of positive and negative electricity, suppose that the rubber is supplied with this fluid from the earth, by the chain which is attached to it, and that the friction of the rubber on the cylinder communicates electricity to the latter, from whence it is collected by the points of the prime conductor, and condensed upon it.

When the chain is taken off, and the cushion insulated, a very small quantity of electricity is produced from the friction of the rubber and cylinder: this serves to shew that the fluid is received by the rubber from the earth; therefore, when it is insulated, as well as the prime conductor, the quantity of fluid retained by the cushion being less than that which is accumulated on the conductor, the former is called minus or negative, and the latter, plus or positive.

When this inequality exists in bodies that are brought within each other's electrical atmosphere, the opposite states combine and restore an equilibrium; but when bodies alike positive, or alike negative, are opposed to each other, they resist with an equal power and elasticity.

This hypothesis derives considerable support from the following experiment:

If the conductor Q, with a small point at O, be placed on a brass rod, connected with the cushion, and another with the brass point, P, be supported by the prime conductor, those bodies which are electrified, will not only be attracted by the conductor, R, but the electrical fluid will diverge in a *conical* form from the point, P, as emitting its electricity, whilst a small faint *globular* flame will be seen on the point, O, as if it were imbibing the electric stream.

GALVANISM,

OR

ELECTRO-CHEMISTRY.

THIS science received its name from Galvani, who is said to have discovered a new electric influence, in the year 1790; but the present state of this subject has so little connexion with those principles which Galvani attempted to establish, that it has received from Sir H. Davy, the name of electro-chemistry.

We are told that Galvani, having one day impaled a frog for the purpose of dissection, he accidentally discovered that when he formed an electric circuit, by means of the animal, the iron spike, and a silver probe, which he happened to employ on this occasion, a convulsive motion was observed amongst the muscles. Struck by this remarkable effect, he was led to make many experiments on muscular irritation in living and dead animals. He also found that by making a communication between the nerves and muscles of animals recently killed, he could readily produce a strong muscular effect. Experiments of this

description induced Galvani to imagine that animals evolved a fluid from the brain, to which he gave the name of animal electricity. He further supposed that this fluid was the agent of the will, and that by being transmitted from the brain, through the nerves to the muscles, it stimulated the muscular action of different parts of the body.

Although this philosopher might be entitled to credit for ingenuity in the formation of his theory, he was totally without proof after he had completed it; this induced Volta and others, who had been favourers of his early opinions, to seek an explanation of the effects they witnessed, from other causes.

It is most manifest that a living animal can produce a muscular action at its own will; but it is still to be explained how the mind communicates with the body to induce this operation. We are not yet sufficiently advanced in the scale of mental perfection to determine this important point, and, most probably, never shall, whilst we remain in the present state of our existence.

It was found that the muscular irritation of dead animals was excited in the greatest degree by the united influence of different metals; this induced Volta to enter upon an extensive course of experiments, to ascertain which metals produced the greatest effect. After a laborious investigation, attended with innumerable experi-

ments, he found that the greatest muscular irritation was produced by the contact of plates of gold and zinc; but on account of the value of the former metal, copper is substituted.

This, in the year 1800, gave rise to the voltaic pile, an apparatus of all others that has been the most instrumental in bringing us acquainted with the chemical department of nature, and as the electrical machine and chemical furnace have made their way into the heavens, it is to be hoped that a few stars will be found to form a new constellation, called the voltaic pile. This pile is composed of a number of circular plates, of zinc and copper, about four or five inches in diameter. If we commence with a zinc plate, a plate of copper is placed upon it, and upon this a circular piece of woollen cloth of the same size, steeped in dilute acid; then a zinc plate, copper plate, and wet cloth, until the pile is completed. If the pile commence with zinc, it must terminate with copper, if with copper, the termination is with zinc.

From the weight of the metals employed in constructing the pile, the dilute acid, which is essential to its action, is soon squeezed out of the cloth, so that it becomes necessary to take down the pile frequently to replenish it.

This inconvenience has been removed by the ingenuity of Mr. Cruickshanks, an English chemist of considerable talents, who constructed a

voltaic trough instead of a voltaic pile, by taking a number of square plates of zinc and copper, soldered together, and placing them edgeways in a wooden trough, about half an inch apart; the cells between the plates receive the dilute acid, which acts for a considerable time, without the necessity of renewal.

Davy, and others, have introduced some variations of this plan, which produce additional convenience; but it does not appear that they have augmented the power, if they have equalled it.

The voltaic apparatus had been produced for some time before its principle was understood, or its real utility known. In the hands of Davy, he penetrated the secret elaboratory of nature, and developed some of her hidden laws.

The decomposition of the alkalis and the alkaline earths, has formed an important æra in chemical science. But those interesting experiments, by which he proves that *all chemical combinations depend upon the electrical capacities of bodies*, have opened the most extensive views in this department.

All bodies in nature, either in the animal, vegetable, or mineral kingdom, have a capacity for electricity, and contain more or less of this universal element. These different capacities constitute the *principle of chemical affinity*. The ultimate particles of different bodies electrically combine with an influence proportional to their

opposite states of electricity, and form chemical compounds, which may again be decomposed, by employing a more powerful electrical agency than that by which the opposite bodies were united.

Dr. Wollaston has shewn that an electrical change takes place at the points of contact, between two solids of different kinds, and that the sensible action of this electric influence, is according to the quantity of surface in contact. If one body be in a fluid, and the other in a solid state, differently electrified, an electrical change or chemical union will take place throughout the whole surface of the solid. If both the bodies are in solution, the ultimate particles of the whole will unite from the opposite states of their electricities, and a third body is formed from the combination of the other two, with character and properties totally different.

For instance, common salt is composed of muriatic acid and soda; the former in a negative, and the latter in a positive state of electricity. These two bodies, previous to their combination, are so destructive of animal matter, that they could not be received into the stomach without producing fatal consequences; yet, chemically combined, they form salt, this useful, harmless, and palatable ingredient of human food.

The electric fluid is an element entirely of the same kind, universally diffused throughout all

bodies; and when the equilibrium of this fluid is disturbed, it will constantly endeavour to restore it.

From this common principle of nature, the whole phænomena of electricity is produced, whether these effects be obtained from the electric jar or electro-chemical trough.

It has been already stated, that the effects which are produced by the electric jar, are obtained by disturbing the electrical equilibrium of the same body, or by bringing the opposite sides of the jar into different states of electricity. When a communication is made between the interior and exterior of the charged jar, the electrical fluid rushes from one side to the other, to restore the equilibrium, which produces sensible electrical effects.

It is the same fluid and same principle, operating in a different way, that produces those effects of electricity, which have received the unappropriate name of Galvanism.

Different bodies being endowed with different capacities for latent electricity, if the ultimate particles of two bodies in opposite states be presented to each other, a sensible effect takes place, and they chemically or electrically combine, which produces a third body, with an electrical capacity different from either of the other two; for the electricity is not equal to that which they possessed in their respective states; consequently, a portion of the combined fluid

belonging to the former bodies is set free, and becomes sensible or active.

From the great relation that exists between the effects of electricity and heat, the preceding principle may be illustrated by the following analogy.

If we take water and sulphuric acid, at the temperature of the atmosphere, and mix them together, an immediate increase of heat takes place, even exceeding that of boiling water. Each fluid has its determinate capacity for latent heat: but when the two fluids are united, the compound has less capacity than the two bodies respectively taken; consequently, a portion of latent or combined heat is set free, and becomes active, which increases the temperature of the mixture.

The principle of electrical action that takes place in the voltaic apparatus, is still obscured by considerable difficulties. The following illustration bears considerable analogy to the preceding, in point of theory.

The dilute acid which is employed to excite electro-chemical action, exists in a negative, and the zinc plates in a positive state of electricity. When the dilute acid is poured into the cells of the trough, an electric action takes place between the metal and the acid, in contact with it; by which means a portion of the metal is dissolved, and a third body, or an oxide of zinc is produced, with less capacity for electricity than the zinc itself.

If we suppose this oxidation to take place on the surface of the first zinc plate in the series, a portion of combined electricity is set free, and this is received by the copper, in contact with the second zinc plate; because the copper has less electrical capacity than the zinc. But the second zinc plate is likewise evolving its electricity, which, being added to that received from the first, is carried through the fluid of the second cell to the negative surface of the copper connected with the third zinc plate; this accumulated quantity of electricity is carried to the next pair of plates, and so on, throughout the whole series; increasing in an arithmetical ratio, directed from one end of the trough to the other; so that the force of the electro-chemical apparatus is according to the area and number of the plates employed.

When a communication is made between the copper and zinc ends of the apparatus, the electric fluid passes in a positive state from the zinc to the copper side of the plates, to restore the equilibrium.

As all bodies possess a particular disposition for electricity, and as chemical affinity is found to depend on opposite states of electricity, the chemical force with which the elements of two bodies unite, can only be proportional to the opposite states of their electrical capacities; so that the ponderable parts may be considered as passive, or merely vehicles for electrical influence;

consequently, the character and properties of bodies generally, are probably, much more dependent upon their electrical states, than upon the properties of their elements.

In this point of view, we may readily perceive the great utility and importance of the electro-chemical apparatus, in decomposing compound bodies and bringing us better acquainted with the elementary principles of nature. Inasmuch as the ultimate particles of two or more bodies unite by their different capacities for the electric fluid, if the body thus constituted, be placed under the influence of the electro-chemical apparatus, (which produces the greatest possible effects of electricity from the uncombined state in which it is evolved,) those particles that were united by an inferior influence, will be mutually disposed to quit each other, and arrange themselves at the positive and negative extremities of the wires, where they may be collected in their decomposed state for further examination.

With the preceding explanation respecting chemical combinations, and the general view of electro-chemical action which is produced by the apparatus, we will now proceed to explain that important experiment of Sir H. Davy's, on which the present theory of chemical affinity depends.

Three jars are placed near each other, one contains a dilute acid, the other an alkali, and the

third distilled water. Let a communication be made between the jars by asbestos, or platina wires, and likewise arm the extremity of the wires at the positive and negative ends of the apparatus with platina; when the positive wire is introduced into the distilled water, and the negative wire into the dilute acid, a portion of this acid will be found to have passed through the body of the alkali, and to have formed itself at the extremity of the positive wire, in the distilled water.

If litmus paper, or any other of the ordinary tests for detecting uncombined acids, be introduced into the distilled water, near the end of the wire, it will be immediately acted upon, and even a sensible portion of the acid employed in this experiment may be obtained from the water.

The rationale of this interesting experiment stands thus: The acid in the jar connected with the negative end of the apparatus, being in a negative state, is influenced by the positive state of the wire contained in the distilled water, and passes from one end to the other by the force of this electrical power; but the acid passes through the alkali in the middle jar, in its transit, without effecting any chemical combination; although, under any other circumstance, it is well known that a very powerful attraction exists between them.

This experiment shews that extremes will

combine and exclude an electrical mean; for the states of the negative acid, and positive electricity at the end of the wire, are in greater opposition than those of the alkali and acid; therefore, the acid passes through the alkali as a mere conductor to a higher state of electricity than that which it possesses.

The important principles which are derived from this experiment, may be further confirmed by changing the position of the jars.

Let the water be connected with the negative end of the apparatus, the alkali with the positive end, and place the acid jar between the other two; in this case the alkalescent, or positive principle, will pass through the acid and form itself at the extremity of the negative wire, in the distilled water.

If a piece of litmus paper be employed in these two experiments, the vegetable blue colour will be turned red when it is placed in the distilled water at the positive end of the apparatus; but if this red-stained paper be introduced into the water at the negative end, the alkalescent principle combines with the acid, and restores the blue colour which had been lost in the preceding operation.

Mr. De Luc has lately opposed the principles of Sir H. Davy, and has endeavoured to controvert his theory of chemical affinity. The electrical column, which he employs on this occasion, is a

very interesting apparatus, constructed in the following manner:

A disk of zinc leaf, about the size of a shilling, is placed upon a piece of silvered paper of the same size, with the metallic surface upwards, then a piece of plain writing paper upon the silvered paper and so on; sixteen hundred series thus constituted, are placed in two glass tubes, the ends of which are hermetically closed with brass caps. The upper extremities of the columns are connected by a wire, and the lower ends are insulated or cut off from any electrical connexion with the earth. A bell is fixed at the lower end of each column, and a clapper is suspended by a silk thread from the cross wire at the top, which hanging immediately between the bells, is attracted by the positive electricity of one of them, and is then immediately driven off to the other, where it gives out the redundant fluid it has obtained, and returns for more. The clapper being thus acted upon by the positive and negative state of the bells, a continued ringing and perpetual motion is kept up without any renewal of the impulse.

The bells of an apparatus of this description, have been kept constantly ringing for upwards of two years; but the intensity of the electrical action, or the velocity of the clapper, varies considerably, although it does not actually stop.

Mr. De Luc infers, from this experiment, that

chemical and electrical action, are distinct principles, and that it frequently happens when the electrical influence is the greatest, the chemical influence is the least, and vice versa. He admits that bodies have different capacities for electricity, and that an electrical change takes place at the surface of different metals, or bodies, in contact, but that this is not the source of chemical affinity.

He states, that the effects of the electrical column just described, arise from the mere contact of the metals, and not from any chemical change on their surfaces; inasmuch as the metals are sealed up, air tight, in the tubes, and shut out from any chemical agencies.

The experiment is certainly very interesting, and gives some plausibility to De Luc's theory, but it will require considerable time before we can give our full assent to this principle.

Even admitting there is no connexion with the atmosphere, it must be shewn that the paper, which is so abundant in the column, does not possess some degree of moisture. A very small portion, in contact with the zinc, might produce a sufficient oxidizement on its surface to account for the feeble electrical influence that takes place between the bells. A careful examination of the metal, after some years of electrical action, may elucidate this point.

The variation which so frequently takes place in the motion of the clapper, will necessarily

lead to some inquiry. It may be doubted whether this change in the electrical power of the column arises from the different quantities of vapour that surround the bells at different times, or from some imperfect connexion between the atmosphere and the interior of the column. It ought to be stated that the whole of the apparatus is covered with a glass receiver, the bottom of which fits into a groove, in a wooden stand, but not air tight; consequently, this exterior covering tends to prevent the moisture of the atmosphere from carrying off different quantities of electricity from the bells.

The construction of this apparatus is so perfectly analogous to the voltaic pile, that it becomes rather difficult to divest the mind of its prejudices, or to suppose otherwise than that it is a modified operation of this principle.

The theory of De Luc, on the difference between electrical and chemical action, he further illustrates by the following experiment:

If the cells of a new electro-chemical trough, which has never received any acid, be filled with distilled water, a gold leaf electrometer will manifest considerable electrical action, from the contact of the water with the metal of the trough, although no chemical action is produced. If acid be added to the water in the cells, the usual chemical effect takes place on the surface of the zinc, and

the ordinary results of the apparatus are obtained; but it is found that the divergency of the leaves of the electrometer is diminished, which De Luc considers as indicating a less electrical intensity in the apparatus, although its chemical powers be greater. In this case it might be doubted whether the augmented electricity is not carried off by the superior quantity of vapour which is produced by the chemical change, when a more direct electrical communication is not made between the positive and negative ends of the apparatus to restore the equilibrium.

It is added, that a common electrical battery may be charged so as to produce a very sensible spark, or shock, by making an electrical communication from the inside to the out, with the positive and negative ends of three or four ordinary electro-chemical troughs, filled with distilled water only, and that the effects thus produced are greater than what could be obtained from the troughs excited with dilute acid.

The following is among the earliest effects which Sir H. Davy produced with the *electro-chemical apparatus*.

From the undecomposable state of the alkalis, they were long considered as simple and elementary substances in nature, and were ranked as such by chemists in general; but Davy, having discovered the powerful influence of the electro-chemical fluid in the decomposition of chemical

bodies in general, submitted a piece of moistened potash to the influence of an electro-chemical battery containing one hundred and fifty square feet, and to his great gratification, soon obtained some metallic globules, resembling quicksilver in appearance, which had the singular property of becoming fluid at the temperature of about one hundred degrees, soft or pasty at sixty degrees, and brittle at thirty-two degrees.

This metal is specifically lighter than water, in the proportion of about seven to ten; it instantly takes fire and decomposes water when it is thrown upon its surface, and the metal is again converted into potash.

This experiment led the professor to discover that potash is composed of the elementary substance, oxygen united with a metallic base; the former in a negative, and the latter in a positive state of electricity.

The powerful affinity by which the oxygen was united with its metallic base, would only yield to the superior influence of uncombined electricity, obtained from the apparatus. This not only proves its importance in chemical research, but likewise serves to demonstrate the chemical axiom laid down by Davy, "that all chemical affinity depends upon electrical influence, and that the power or force of combination depends upon the electrical capacities of the bodies."

When potash is exposed to the influence

of the apparatus, the electrical affinity that exists between the oxygen of the alkali and the positive end of the wire, connected with the battery, is greater than the electrical influence of the elements themselves; consequently, the oxygen leaves the metallic base, and forms itself at the end of the wire. On the other hand, the metal in a positive state, having a greater affinity for the negative wire than the oxygen, readily leaves the latter to combine with the former, from whence it is collected and put into Naphtha to preserve it from its re-union with oxygen.

This, however, is not the ordinary mode by which the metal, potassium, is generally obtained for different chemical purposes.

Gay Lussac and Thenard, two ingenious French chemists, found that potassium might be procured in a gun barrel, by exposing a mixture of potash and iron shavings to an intense heat; this experiment depends on the preceding principles, and is a much more easy manner of obtaining the metal.

Similar experiments have been made with the electro-chemical apparatus, upon soda, barytes, strontian, lime, and magnesia, all of which were considered as elementary bodies, but are now found to possess metallic bases.

As the influence of the electro-chemical apparatus depends on the quantity of metallic surface employed, batteries have already been formed,

of twenty thousand feet, by small plates about four inches square.

A gentleman of the name of Chiltern, has lately constructed an electro-chemical apparatus, with zinc and copper plates, about six feet long, and four feet wide, which are capable of instantaneously fusing many inches of platina wire of considerable thickness.

The *reproduction of metals* from their solution, affords a number of interesting experiments which illustrate Davy's theory of chemical affinity.

If the ends of the positive and negative wires of the electro-chemical apparatus be brought into a solution of sulphate of copper, nitrate of silver, muriate of tin, or acetate of lead; the metals, respectively, will form and chrystalize in the most beautiful manner at the end of the negative wire, and the oxygen with which the metal was previously combined in the state of a salt, is evolved in a gaseous state from the positive end.

According to what has been already stated, the negative wire has greater affinity for the metal than the oxygen: the oxygen has likewise greater affinity for the positive wire than the metal; and from this mutual disposition to separate, the two bodies form at the extremities of the wires which are connected with the apparatus.

The *decomposition of water* is a beautiful experiment, and shews the utility and convenience

of the electro-chemical apparatus; although, in justice to the original experimenter, and the general influence of electricity, this decomposition of water was effected many years before the electro-chemical apparatus was discovered.

Mr. Cavendish enclosed water in a glass tube, and after having passed a very considerable number of electrical discharges through it with a common battery, he decomposed the fluid, and obtained a gaseous product in the tube, which he found to be composed of those two elements to which we now give the names of oxygen and hydrogen. He likewise ignited these mixed gasses and reproduced water; thus proving both analytically and synthetically, at this early period of chemical science, that water is compounded of the two elements, oxygen and hydrogen. But this experiment, which is so laborious with the agency of the common electrical battery, may be instantly produced by electro-chemistry, with a single trough. As soon as the two ends of the wires are brought into a glass of water, an immediate decomposition takes place; oxygen evolves from the end of the positive, and hydrogen from the end of the negative wire; these gasses may easily be collected in an inverted jar full of water, and recomposed by setting them on fire, either with the electric spark or a lighted taper.

The rationale of this experiment is, that as water is composed of the elements, oxygen and

hydrogen, the first in a negative, and the second in a positive state, these elements only possess a given quantity of electricity; so that under the influence of the apparatus, they have a greater affinity for the two extremities of the wires, than for each other; consequently, leave the inferior for the superior power.

The *identity of the electrical and electro-chemical fluid,* is confirmed by a variety of experiments, which may be readily effected, either by one means or the other.

The electrical fluid obtained from the common machine will set fire to oil, alcohol, æther, phosphorus, gunpowder and other inflammable bodies; and the whole of these are also easily ignited by the electro-chemical fluid.

Gold, silver, and other metals, may be beautifully oxidized on the surfaces of cards or glass, by means of the electric battery, and a complete combustion, or oxidizement, may be instantly effected with the electro-chemical apparatus.

If a living, or recently killed animal, be placed on an insulated stool, and electrified, a very considerable muscular action takes place; but the same effects are powerfully produced by the electro-chemical fluid.

The evolution of light and heat, from burning charcoal, is peculiarly distinguishable among the combustion of inflammable bodies, by electro-chemistry. If two pieces of charcoal be con-

nected with the positive and negative ends of the apparatus, on bringing the points in contact, the most brilliant light imaginable is evolved, which instantly terminates when the connexion is destroyed.

The effects of this experiment are equally striking if the same points be brought into an exhausted receiver, or in a jar of hydrogen or nitrogen gas, or in any other situation where no oxygen can be obtained.

If, by combustion, we mean an evolution of light and heat, the general principles would not be sufficient to explain the effects that are produced by the preceding experiments. According to the Lavoiserian theory, the presence of oxygen is necessary to produce combustion; but in an exhausted receiver, or in hydrogen or nitrogen gasses, there is an equal evolution of light and heat from the charcoal, although there is no oxygen either free or combined.

When we investigate the laws and operations of nature, we are more inclined to speculate upon the ponderable than the imponderable parts, and therefore consider the earth to be composed of a certain number of sensible elements, possessing distinct principles; and that the various properties of bodies depend upon the character of the elements that compose them; also that the change of property is produced by the change of elements.

But every change of property is dependent upon a chemical influence. The particles of different bodies which are aggregated, merely by attraction of cohesion, undergo no change; so that to obtain fresh properties, a chemical union must take place; and, inasmuch as all chemical combination is purely dependent upon the opposite electricities of bodies, and not upon any peculiar disposition inherent in the particles themselves, it seems, from this view of the subject, that the chemical property of compounds is more peculiarly derived from the natural state of their electricities, than from any effects of their elements, exclusive of electrical influence.

Different quantities of the same elements, combined by electricity, produce different properties in the bodies that they constitute. For instance; the atmosphere which we breathe is chiefly composed of oxygen and nitrogen, in the proportion of twenty-one parts of the former, to seventy-seven parts of the latter. These two elementary gasses form a mere mechanical mixture in our atmosphere, properly suited to the purposes of animal respiration; but it is well known, that if a portion of atmospherical air be electrified for some time, a chemical combination takes place between the elements, and a yellow acidulous gas is produced; which being condensed, constitutes nitrous acid. This experiment shews us how much the properties of bodies result from their electri-

cities: here are the same elements in a state of mechanical mixture, constituting an air on which the generality of animals are dependent for their existence; but by the agency of electricity it is converted into a gas, which would be instantly fatal to any animal confined in it.

If a portion of oxygen be abstracted from nitrous gas, it constitutes the *nitrous oxide;* a gas which possesses properties totally different from either of the other two. This gas may not only be safely breathed, but it likewise communicates the most delightful sensations; it exhilarates the animal spirits, and produces a great degree of mental energy. These effects are not unfrequently indicated, by singing, dancing, laughing, and other emotions that point out the great gratification which is received by those that breathe it.

The analysis of this gas shews that it is composed of thirty-six parts in one hundred of oxygen, and the rest nitrogen. In the atmospheric air there are twenty-one parts oxygen, and the remainder nitrogen. If we add fifteen parts oxygen to the atmosphere, the quantities of the elements would be the same in both cases; but the effects, or properties, are still widely different; the additional portion of oxygen would make no difference whatever in our sensations, and affords, amongst many others, a strong proof that the properties, principles, and effects of this and other

bodies are more dependent upon their electrical dispositions, than the nature of their elements, and that ponderable masses of our earth are but vehicles of electricity.

If these principles be admitted, it will be easy to explain those brilliant effects which are produced during the combustion of charcoal, by means of the electro-chemical apparatus; not only in atmospheric air, but also in an exhausted receiver, or in a jar of hydrogen or nitrogen gas.

Combustion is generally considered as the result of a chemical combination, between an inflammable body and oxygen.

Combustible bodies have great capacity for electricity, and therefore possess a positive state; but oxygen, of all other elements, has the least electrical capacity, consequently exists in a negative state.

Let us imagine the combustible body, and oxygen withdrawn, or separated from their electricities, the opposite electricities will combine, and a sensible evolution of light and heat is produced, whether the ponderable elements be present or not.

According to this principle of combustion, the sensible masses, or bodies employed, are only necessary to the evolution of light and heat, from their capacity for electricity, or affording vehicles for a positive and negative influence; therefore, the force of combustion depends upon the most

opposed state of the electric fluid, as well as the quantity supplied; consequently, when an inflammable body is subjected to the influence of free electricity, obtained from the electro-chemical apparatus, the evolution of light and heat is no longer dependent on the limited capacity of the body for the electric fluid, but upon the opposite states which are produced at the extremities of the positive and negative wires.

Pursuing this view, we have all the principles of combustion in an electric spark, whether it be obtained from the prime conductor of an electrical machine, or from the two ends of the electro-chemical apparatus. For light and heat are evolved in both situations, and under the same principles of electricity as those that produce combustion or chemical combination between the ultimate particles of sensible masses.

Combustion, therefore, seems to result from the opposite states of the electrical fluid, either independent and uncombined, or obtained from certain bodies in which it previously resided; it likewise appears, that all chemical combinations in nature are produced by the influence of electricity, and that the force or power of combination is dependent upon the electrical states of the bodies.

CHEMICAL PHILOSOPHY.

ALL the combinations of nature, amongst the particles of unorganized matter, are either *chemical* or *mechanical.*

From the great extent of chemical operations in nature, and the importance of chemistry in the arts and manufactories of this and every other civilized country, it forms a subject of high consideration and great advantage to the general interests of mankind.

The science of chemistry not only promotes our pecuniary views, but is absolutely essential to a knowledge of medicine, and has already effected considerable reform in this important department of human pursuit. Instead of those numerous drugs heaped together in the same prescription, some of which were neutralizing the effects of others, and occasionally producing compounds in the stomach, more mischievous than useful, we find the best modern practitioners sparing of medicine even when they see it necessary to aid the efforts of nature: and in all cases it is composed of a small number of drugs, so that by being well acquainted with the chemical properties and principles of those that are employed, they can confidently look for results which the earlier physicians, even amongst the most intelligent, could only obtain from a blind practice.

The study of chemistry not only secures our health and promotes our interests, but the beauty and singularity of the effects that take place during a variety of experiments, add to our pleasures and amusements; and, above all, it extends our view of the infinite wisdom and admirable design of the first cause, and points out to us the innumerable blessings that we are perpetually enjoying in the present state of our being.

The subject of chemistry includes the most important phænomena of nature; the causes of rain, hail, snow, winds, volcanos, and even earthquakes cannot be explained without its aid. The vegetation of plants, and some of the most important functions of animals, have received all their illustration from this source, and in the arts and manufactories we may trace its decided operation in glass-making, lime-burning, soap-making, bleaching, dying, calico-printing, malting, brewing, wine-making, vinegar-making, and in converting earths into porcelain, and ores into metals. Even agriculture owes much of its improvement to chemistry; it teaches us how to analyze soils that have been the most productive, and ascertain the proportion of earths and other substances that enter into their composition, and in this practical way brings us better acquainted with the fitness of different soils for the various productions of nature.

CHEMICAL AFFINITY,

IS that disposition which the particles of particular bodies have to unite in preference to others, and constitutes the fundamental principle of chemical science.

It is only within a few years that this power of combination has been found to depend upon the electrical state of bodies, and inasmuch as all bodies in nature have a greater or less capacity for electricity, innumerable instances of chemical affinity might be produced to illustrate this theory; however a few only will be selected, but those will be such as either convey useful information, or produce some interesting or striking experiment.

To a solution of the salt, called muriate of of lime, add a few drops of a solution of potash, and the lime will be instantly precipitated in a solid state, quitting its combination with the muriatic acid; but if a small portion of dilute sulphuric acid be added, the lime is immediately taken up, and the whole fluid becomes again transparent and colourless.

According to the theory that has already been explained, the changes would stand thus; the muriatic acid is in a minus state of electricity, the lime is plus, and on this principle they com-

bine; but potash has a greater electrical capacity than lime; so that when it is presented to the muriatic acid they instantly unite, excluding the lime, as it possesses a mean state of electricity; but sulphuric acid has more affinity for potash than muriatic acid; consequently, the latter acid is thrown out of its combination with the potash and enters again into union with the lime which has been already displaced.

The *formation of writing ink* illustrates the principle of chemical affinity.

If a solution of sulphate of iron or green vitriol be mixed with the tincture of galls, a black precipitate is produced, which, with the addition of a weak solution of gum arabic to suspend it, constitutes common ink.

The chemical combination is between the iron and the gallic acid of the nut-galls. If dilute sulphuric acid be poured into the ink it combines with the iron, displaces the gallic acid, and decomposes the ink by rendering it colourless.

Ink stains may be removed from linen by means of dilute sulphuric acid, but great care must be taken that the acid be properly diluted before it is employed, and that the cloth be well washed in water previous to its being dried.

The ink in old writings frequently loses its blackness, but retains a reddish appearance. This effect is produced by the evaporation of the gallic acid which leaves the oxide of iron; if the paper or parchment be washed over with the

tincture of galls, the gallic acid will again combine with the iron and render the characters blacker and much more legible than before.

If a few drops of a solution of potash be added to a solution of sulphate of copper or blue vitriol, the hydrate of copper is precipitated, which may be collected from the fluid by evaporation and readily formed into a globule of pure copper upon a piece of charcoal, by means of the blow pipe.

If a few drops of the alkali ammonia be let fall into a jar of water containing a small portion of sulphate of copper in solution, the fluid instantly obtains the most beautiful blue colour; but if a few drops of dilute sulphuric acid be added to neutralize the alkali, the blue colour instantly disappears.

If a piece of polished iron be introduced into a solution of sulphate of copper or blue vitriol, the copper precipitates in its metallic state, and forms a coating on the surface of the iron.

In this experiment the sulphuric acid which is united with the copper having more affinity for iron than copper, quits the latter and combines with the former, and the copper is deposited on the surface of the iron by the mere gravity of the metal. A considerable portion of the purest copper is obtained in this way at Pary's Mountain, in the Island of Anglesea.

The chief production of this mine is sulphuret of copper, and the sulphur is to be separated

from the copper by many tedious operations; but sulphate of copper is likewise naturally produced; and being soluble in water, the fluid, found in the cavities of this open mine, is pumped into shallow ponds, containing refuse iron, and the copper deposits upon its surface. This being frequently washed off, presents a fresh surface of iron for a fresh deposition of copper, and thus the process is carried on until a sufficient quantity is obtained at the bottom of the pond; it is then taken out and exposed to a furnace, which combines the whole into a solid mass of copper fit for sale.

If a solution of muriate of lime be added to a solution of carbonate of soda, the two fluids immediately combine and form a solid. This is an instance of compound chemical affinity, produced in the following manner: The muriatic acid leaves the lime to combine with the soda, and forms muriate of soda or common salt. The carbonic acid which is thrown out of its combination with the soda, unites with the lime that has lost the muriatic acid, and forms carbonate of lime or common chalk; so that common salt and common chalk are the results of this chemical change amongst the elements that have been employed.

If two solid bodies, called nitrate of ammonia and sulphate of soda, be pounded together in a mortar, they will combine and form a perfect fluid.

The principles connected with the solidification and liquifaction of the bodies in the two last experiments are of considerable interest in the subject of chemistry, and shew the great *change of capacity for caloric* which takes place amongst the elements of bodies when they chemically or electrically combine.

HEAT OR CALORIC.

THIS element exists both in a latent and active state.

Latent heat is the repulsive, modifying power which is combined with different bodies in variable proportions, and produces their different specific gravities; but bodies change their capacity for heat, as they change their electrical capacity.

Active heat is not essential to the constitution of the body; but whilst it resides in it, it has a modifying power, or like latent heat is repulsive amongst its own particles. In every chemical union there is a change of temperature, the active heat of the compound being either increased or diminished.

Bodies become *solid, fluid,* or *gasseous* according to their capacity for heat.

Every body in nature has a certain capacity for heat, even ice contains a portion of latent or combined heat.

If a piece of solid ice be put into a vessel and exposed to the active heat of an ardent fire, it soon begins to liquify and is converted into water; but the water is as cold as the ice until the whole is melted. The capacity of water for heat is greater than that of ice, therefore active heat must become latent to constitute water, and as fast as the heat enters the vessel it is instantly absorbed by the ice until the whole is melted; but as soon as the solid is converted into a fluid, any additional heat becomes sensible or active heat, which by accumulation, increases the temperature of the fluid until it boils. When steam is formed, no further increase of temperature takes place, unless it be confined in the vessel; for as fast as the active heat enters the water it becomes latent, and converts a portion of the water into steam.

Steam escaping from water, under the ordinary pressure of the atmosphere, is about one thousand eight hundred times rarer than the water in which it is formed; and it has a temperature of two hundred and twelve degrees, which will support a column of mercury thirty inches high; pressing with a force of fifteen pounds on a square inch; but if the steam be retained in the vessel until its temperature is increased to two hundred and fifty

degrees, its pressure or elastic power is increased accordingly, and it will support a column of mercury sixty inches, or press with a force of thirty pounds on a square inch. At a temperature of two hundred and seventy-five degrees, the column of mercury will be ninety inches, and pressure forty-five pounds. Temperature of steam being two hundred and ninety-four degrees, the column of mercury would be one hundred and twenty inches, and pressure sixty pounds on each square inch. At three hundred and nine degrees of temperature, the elastic force of the steam would support a column of mercury one hundred and fifty inches high, and presses with a force of seventy-five pounds on a square inch.

In this manner the elastic power of steam keeps increasing with the temperature, to an indefinite extent, which renders steam so highly important as a moving power in the operation of steam engines and other machines.

From the preceding considerations, it is obvious that when solids pass into a fluid, or fluids into a gasseous state, *heat* is *absorbed;* on the contrary, when bodies pass from the gasseous into the fluid, or from the fluid into the solid state *heat* is *evolved.*

If sulphuric acid and water be mixed together at the temperature of the atmosphere, the heat evolved raises the temperature to above the boiling point of water, and the volume of the mixed fluid is diminished accordingly.

If a saturated solution of sulphate of soda be poured in a boiling state, into a common phial, and be covered over with bladder, on pricking the bladder, when the fluid is cold, the atmospherical pressure produces an immediate chrystalization of the dissolved salt, and a considerable evolution of heat takes place, whilst it is passing from a fluid into a solid state.

When muriatic acid is poured upon sulphate of soda, the salt dissolves and is converted into a fluid state; but the temperature of the muriatic acid will fall some degrees below the freezing point of water. In this experiment the active, or free heat of the muriatic acid, is taken up and becomes latent to liquify the solid; for fluids have an increased capacity for heat.

When fresh fallen snow is mixed with muriate of lime, these two dry substances rapidly combine and liquify; the temperature may be reduced in this manner so low as to freeze quicksilver.

During a frost there is an evolution of caloric, for fluids pass into a solid state, consequently lose their capacity for heat. On the contrary, during a thaw, there is an absorption of active heat which becomes latent. It is on this account that we frequently feel greater sensations of coldness during a thaw, than when it freezes.

Thermometers and *Pyrometers* are instruments which are used for ascertaining relative degrees of sensible heat, by the expansion or contraction of fluid or solid bodies.

The *thermometer* which is generally employed in this country, was constructed by Fahrenheit, a Dutchman, in the following manner: He filled a glass bulb and tube with mercury, and placed it in the greatest degree of heat which the mercury would support, without being converted into a gasseous state; in this situation he closed the end of the tube, and then introduced the bulb into a mixture of salt and snow, to produce the most diminished temperature, which constituted the zero, or lowest point of the instrument. The distance between these extremes of the scale he divided into six hundred parts. When this graduated scale was put into water that was just beginning to freeze, it was found that the mercury stood at the thirty-second division, which is called the freezing point; when it was introduced into boiling water, the mercury rose to the two hundred and twelfth, which forms the boiling point. The thermometers that are graduated according to Fahrenheit's scale, are made by ascertaining the boiling and freezing point, then dividing this difference into one hundred and eighty divisions; carrying these equal divisions upwards and downwards as far as the tube will admit.

Cooling mixtures are now readily formed which will reduce the thermometer to forty degrees below zero, and at this point quicksilver freezes. It is stated that the temperature has

been recently reduced to one hundred and ten degrees below zero; in this state alcohol was converted into a solid mass.

Mr. Dalton of Manchester, objects to the equal divisions of Fahrenheit's scale; he shews that equal increments of heat have not equal expansibilities, and has graduated a scale accordingly, in which the divisions regularly vary from the lower part of the scale upwards.

Pyrometers are employed to point out the expansion of solid bodies, and compare the relative expansibility of metals at different temperatures.

The usual method is to place metallic rods in such situation, that during their expansion by additional heat, they may act against a compound lever; one end of which serves as an index to mark the relative expansion of the metal upon a graduated scale.

Wedgwood formed a pyrometer for measuring great intensities of heat, from the contractibility of small pieces of clay under an increasing temperature.

Some bodies *conduct heat* with much more facility than others.

If a rod of iron and glass be placed with one of their ends in the fire, the opposite end of the iron will become quite hot before that of the glass rod is scarcely warmed.

When we take hold of a piece of iron and a piece of wood, we find the metal much colder

than the wood, though the thermometer may indicate the same temperature in both.

The different degrees of warmth which we experience from various kinds of cloathing, arises from the conducting capacities of the substances that constitute them; thus, fur and woollen are worse conductors of heat than silk or linen, therefore, one is worn in winter and the other in summer.

Our *sensations of heat and cold* arise from the actual motion of the particles of caloric.

If the hand, for instance, be introduced into water of greater temperature than the body, the particles of heat, from the general principle of equilibrium, pass from the water to the hand; but if the water be colder than the hand, the heat passes from the hand to the water, and the degree of sensation in either case, is according to the quantity of heat transmitted in any given time. When the equilibrium obtains, or the motion ceases amongst the particles of heat, our sensations of heat or cold likewise terminate.

There have been many opinions respecting the principle of light and heat, but the recent experiments of Herschel, Ritter, and Wollaston, seem to determine that *light and heat are distinct bodies*, governed by the same optical laws.

If we place two concave reflectors of about twelve inches in diameter, eight or ten feet asunder, and put a lighted taper in the focal point of

one of the reflectors, the light will be reflected in parallel rays, and converged in the focal point of the other.

If a piece of warm iron be placed in one of the foci, it will raise the temperature of the thermometer in the other. Or if a piece of red-hot iron be placed at one end, it will set fire to an inflammable body placed at the other; although the iron would not ignite it at a foot distance if the reflectors were removed; all of which tend to shew that heat radiates and follows the same laws as light.

What has been already detailed may serve to give some general idea of the importance of these imponderable elements, Light, Heat, and Electricity, in the extensive field of nature. The next observations will apply to those tangible and ponderable masses which constitute the earth and all its inhabitants.

ELEMENTARY SUBSTANCES.

CHEMISTS have been very much divided with respect to the number of those bodies which are called elementary: the progress of the science has, however, done much in diminishing them.

Ancient philosophers supposed there were only four elements, fire, air, earth, and water; but whatever may be our opinions respecting fire, it is generally agreed that the other three are compound bodies.

Modern philosophers comprize the elements of nature under the following heads of *oxygen*, *hydrogen*, *nitrogen*, *carbon*, and the *metals*. The chlorine of Davy, and the iodine of the French chemists, may be added to this number. Sulphur, phosphorus, earths, and alkalis were lately considered as elementary substances; but the decomposing power of the electro-chemical apparatus, and other means, have proved these bodies to be compounds, and perhaps 'ere long, some more may be rejected: the elementary state of nitrogen has already been strongly suspected.

If it be believed that the properties of bodies depend on their electrical capacities, the ponderable substances of nature will be considered as merely passive, and the various properties which are now ascribed to them will be resolved into the different states of electrical capacity that they possess.

Oxygen is generally ranked first amongst the elementary bodies, on account of its importance in supporting the principle of vitality.

This element constitutes a portion of the animal, vegetable, and mineral world, and modified by heat, is capable of a solid, fluid, or gasseous state, but the simplest is gasseous.

In the animal body, oxygen is united with nitrogen, hydrogen, carbon, sulphur, phosphorus, lime and iron. Vegetables are chiefly composed of oxygen, hydrogen, and carbon. Oxygen, sulphur and arsenic are mineralizing principles that unite with metals and form their respective ores.

If we take a hundred parts of the *atmospherical air* which we breathe, according to Davy's analysis, there are twenty-one parts oxygen, seventy-seven parts nitrogen, with one part of carbonic acid gas, and one of vapour.

These elements, and in these proportions, are found in the atmosphere on every part of the earth's surface, whether it be on the mountain's top, the valley, or the centre of the crowded city. It is not to be inferred from this that the atmos-

pherical air is of equal salubrity in all these places. The healthful state of the air does not depend upon what may be considered as the proper atmosphere, but upon those foreign ingredients which are constantly entering into it.

In the midst of large cities, and particularly where there is not a proper attention to cleanliness, a putrid decomposition is constantly taking place amongst dead animal and vegetable matter. From this fertile source obnoxious gasses constantly evolve and mix with the atmosphere; these are taken into the lungs in the act of animal respiration, and produce many diseases in the animal system.

In flat and swampy countries a putrid exhalation of vegetable matter is constantly vitiating the air; and in the neighbourhood of lead and copper works the poisonous elements of these metals are driven off in a gasseous state, and inhaled, to the serious injury of the inhabitants.

It may readily be inferred from these observations, that the most healthy situation is in a dry and rather elevated country, and at a sufficient distance from any of those offensive sources that have been mentioned.

The sea shore is recommended to the valetudinarian, that he may inhale the pure and refreshing breeze from the bosom of the ocean, uncontaminated with morbid effluvia.

Atmospherical air supports animal life, but it is

the oxygen gas alone that undergoes chemical change; the nitrogen is inspired, and expired unaltered.

When atmospherical air enters the lungs, it contains twenty-one parts oxygen, seventy-seven nitrogen, one part carbonic acid gas, and one part vapour; but when it is expelled, it is found by analysis, to have lost nearly the whole of its oxygen, and to have increased the carbonic acid gas from one to ten per cent.

It was supposed by Dr. Priestly, that the oxygen entered into combination with the blood in the lungs; but more recent experimenters have shewn that the quantity of oxygen gas necessary to enter into combination with carbon, to constitute the additional quantity of carbonic acid gas which is found in expired air, is exactly equal to the quantity of uncombined oxygen that has disappeared; consequently, this portion cannot unite with the blood and the carbon likewise.

But the next question is, how has the carbon been obtained? By what means has it been evolved from the system and carried to the lungs? or, how has it been separated from the blood in the lungs so as to combine with the oxygen of the atmosphere in that situation? These are questions which have never yet been answered.

This subject of animal chemistry is of all others the least understood. Mankind is constantly speculating and theorizing, but it seems, with-

out the probability of success. We are sensible that many important chemical changes are constantly going on in the province of vitality; but they are performed with such secrecy in the chemical elaboratory of nature, that man, in his present condition, seems too low in the scale of intelligence to be able to penetrate it.

Oxygen gas supports combustion as well as animal life.

If a lighted taper be placed in a limited quantity of air under a glass receiver, over water, the flame is soon extinguished, and the water rises to a certain height in the interior of the receiver. On examining the remaining air, it will be found to have lost its oxygen, and to have increased its carbonic acid gas; but the bulk of the carbonic acid gas is less than that of the oxygen gas previous to the combustion, which causes the water to rise in the vessel until the densities of the interior and exterior air become equal.

The following is the rationale of combustion: The wax or tallow of the inflammable body is chiefly composed of hydrogen, and a portion of the wick is carbon. During combustion one part of the oxygen of the atmosphere combines with the hydrogen of the inflammable body and forms water, and the other part unites with carbon and forms carbonic acid gas, until nearly the whole of the oxygen gas is taken up, or till there is not sufficient to support combustion.

The succeeding experiment points out the importance of oxygen in supporting combustion.

Take three small jars, fill one with oxygen gas, the second with air from the lungs, and leave the third in its ordinary state.

If a lighted taper be introduced into the jar containing the atmospherical air, it will continue to burn in its usual way. If the taper be put into the jar containing air from the lungs, it is instantly extinguished from the want of oxygen gas; but if the taper with its expiring spark, be brought into the jar filled with oxygen gas, it will be instantly rekindled, and burn with an intense light and splendour.

Acids are compound bodies, formed by the combination of oxygen with certain bases. Acids have a low or negative state of electricity, which arises from the quantity of oxygen they contain; for oxygen, of all other bodies, possesses the least electrical capacity.

The various acids which are obtained from the animal, vegetable, or mineral kingdom, are individually capable of combining with the alkalis, alkaline earths, and metals, and from these combinations, a very useful and extensive class of salts is produced.

It is intended by the Lavoiserian Chemical Nomenclature, that the names of different substances should express their composition, which not only assists the memory, but likewise serves

to communicate a considerable portion of chemical information. The following example will illustrate this view.

Sulphuric acid, for instance, was formerly called oil of vitriol; this gives no idea whatever of its composition, but its present name indicates that this acid is composed of the base sulphur united with the acidifying principle, oxygen.

Sulphuric acid may be combined with all the alkalis, alkaline earths, and metals, and form an extensive class of salts, called sulphates: thus we have sulphate of potash, sulphate of soda, sulphate of ammonia, sulphate of barytes, strontian, lime, and magnesia. When united with the metals, we have sulphate of iron, sulphate of copper, sulphate of lead, sulphate of zinc, &c. &c. All the other acids may be passed through a similar combination.

Oxygen has, till lately, been considered as the only source of acidity, but the French chemists have discovered an elementary substance, which they call iodine, that combines with hydrogen, and forms an acid.

Certain bodies, or bases, combine in different degrees with the acidifying principle, oxygen. When the base is completely saturated it forms a perfect acid, and the name of its base terminates in *ic*, as sulphur saturated with oxygen forms sulphuric acid. When the base is not saturated with oxygen, it forms an acid, called *sulphureous*

acid; the termination of the base being in *ous*. These observations apply generally to the different acids.

To form *sulphuric acid*:—If ignited sulphur be introduced into a jar of oxygen gas, a rapid and brilliant combustion is produced, and the jar becomes filled with a dense white vapour, composed of sulphuric acid; this is rapidly absorbed by a small portion of water left at the bottom of the jar, which renders it acidulous.

The next object is to separate the sulphuric acid from the water. Water boils at the temperature of two hundred and twelve degrees, but sulphuric acid requires nearly a temperature of five hundred degrees; therefore, if the temperature of the sulphuric acid and water be raised to two hundred and twelve, and be kept under five hundred degrees, the water will be driven off in the state of vapour, and the sulphuric acid left behind; it is called dry or concentrated sulphuric acid, in proportion to the quantity of water that is driven off.

The suffocating vapour that is produced by burning a common match in atmospherical air, is sulphuric acid vapour produced by the chemical union of the oxygen of the atmosphere with the sulphur.

Phosphoric acid may be formed upon a similar principle, by burning a small piece of phosphorus in a jar of oxygen gas, which produces an intense

light, and a very beautiful effect in a darkened room.

Nitric acid may be obtained from its elements oxygen and nitrogen, by inclosing a portion of atmospherical air in a glass tube, and passing a number of electrical discharges through it, with a common electrical battery. The ordinary mode of obtaining nitric acid is by pouring sulphuric acid upon nitre, which is called nitrate of potash. In this process the sulphuric acid having more affinity for the alkali than the nitric acid, the latter is set free, and the former forms a sulphate of potash.

Muriatic acid has been supposed to be formed of oxygen united with a peculiar base; but these have never been completely separated. Sir H. Davy considers muriatic acid to be composed of a new element, which he discovered and called chlorine, united with hydrogen.

The usual mode of obtaining muriatic acid is by pouring sulphuric acid upon common salt or muriate of soda. The sulphuric acid sets free the muriatic acid, and combines with the soda, forming sulphate of soda or Glauber's salt.

Carbonic acid is formed by the union of the elementary principle carbon with oxygen, like all the preceding acids, it is plentifully produced by the hand of nature in the mineral world. Combined with lime, it forms those immense mountains of marble, limestone and chalk, which

are so abundantly distributed over different parts of the earth.

Carbonic acid gas is produced by burning a piece of carbon or charcoal in a jar of oxygen gas. This air will neither support flame or animal life; and from this circumstance many persons lose their lives by imprudently sleeping in a room where a chafingdish of burning charcoal is placed.

Carbonic acid gas is plentifully produced in caverns surrounded by calcareous earths. As this gas is one and a half times heavier than atmospherical air, it frequently forms a stratum at the bottom of the cavern. In the Grotto del Cani, near Naples, there is a stratum of this gas, about two feet high: if a dog, or any other animal that has its nostrils within two feet of the ground, be dragged into this cavern, it is speedily destroyed, although a man may enter it with perfect safety.

Chrystalized masses, called stalactites, are frequently formed in caverns. These are carbonates of lime, chiefly produced by the deposition of the lime that is held in solution in water, by means of the carbonic acid of the caverns.

Carbonic acid gas frequently forms a stratum on the surface of the water, in a well that has been undisturbed for some time. If quick or fresh lime be sifted into the well, the carbonic acid gas will combine with the lime as it descends,

and a person may immediately afterwards go down with perfect safety.

Carbonic acid gas is evolved in considerable quantities from the surface of fermenting liquors, and is the result of a chemical change amongst the elementary principles of the fermenting fluid. When the upper part of the vessel is filled with this gas, it falls over the sides by its superior gravity to that of the atmosphere; and if a lighted candle be brought near to the vessel, it is instantly extinguished by the invisible fluid.

The usual mode of obtaining carbonic acid gas for chemical experiments, is by pouring dilute sulphuric acid upon chalk or marble, which are carbonates of lime. The sulphuric acid combines with the earth and sets free the carbonic acid gas which is collected in an inverted jar of water.

If lime-water be poured into a jar filled with this gas, the lime is taken out of its solution in the water, and combines with the acid, forming an insoluble substance, called carbonate of lime.

The weight of this gas is pleasingly illustrated by pouring the invisible fluid from one vessel into another, upon a burning taper, by which it is immediately extinguished.

If a piece of burning paper be put into a jar of carbonic acid gas, the vapour becomes entangled in the gas, and shews its situation and density. This gas may be poured from one vessel into another, and will extinguish a burning taper.

Although carbonic acid gas is injurious in the lungs, it is much employed in the stomach, to brace the relaxed muscle by its astringent powers.

This gas is united with water, partly by chemical combination, and partly by mechanical power. When a small portion of soda is introduced, it forms soda water; with iron in solution, pyremont water, &c. These fluids are now frequently drank both for pleasure and for medicinal purposes.

Excellent soda water is instantly made in the following manner: Dissolve a portion of the concrete acid of lemon and the super-carbonate of soda, then put the fluids into two different bottles and keep them corked for use. When the soda water is wanted, pour some of the alkaline fluid into a tumbler, and as much of the acid into another glass as is found necessary to saturate the alkali, or to render the liquor palatable; then pour the two together, and instantly drink it off. In this case the citric acid combines with the soda, and sets free the carbonic acid in a gasseous state, which rapidly escapes in an abundant quantity, from the surface of the mixed fluids.

Some bases combine with such an inferior quantity of oxygen as to possess no acid properties; these are called *oxides*. The black scale which is formed on the surface of a fire poker by constant use, is an oxide of iron, or a chemical

combination effected through the medium of heat, between the oxygen of the atmosphere and the metallic surface of the iron.

If lead be exposed to the fumes of hot vinegar the oxygen of the acetous acid combines with the metal and forms an oxide, called white lead.

When dilute sulphuric and nitrous acids are poured into the cells of the electro-chemical apparatus, the oxygen of the acids combine with the zinc and forms an oxide of zinc.

When a drop of water rests on the surface of polished iron it forms red rust, which is a true oxide of iron. In this case a decomposition of the water is produced, for the oxygen combines with the iron, and the hydrogen escapes from the surface. If red hot iron be immersed in water, it immediately decomposes it; the iron is oxidized by the oxygen of the water, and the hydrogen escapes in a gasseous state.

A beautiful instance of oxidation is produced by burning iron wire, or a watch spring in a jar of oxygen gas; it likewise produces a conclusive illustration of the Lavoiserian principles of combustion.

If a piece of iron wire be accurately weighed, and also the oxygen gas in which it is about to be burnt, it will be found, after combustion, that the oxide is heavier than the wire, by the weight of the oxygen gas which enters into a solid state during combustion.

Oxygen enters into combination with most of the metals, in a natural state, and forms oxides or ores: from these the metals are obtained pure, by driving off the mineralizing principles through the application of heat.

Iron, zinc, lead, and tin, amongst the ordinary metals, are easily oxidizable. Platina, gold, silver, and copper have much less affinity for oxygen.

Hydrogen as well as oxygen still remains an undisputed element; it exists in a state of positive electricity; is found in the three kingdoms of nature, and chemically combines with sulphur, carbon, and phosphorus. Carburetted hydrogen gas is a frequent product of coal mines; this often mixes with oxygen gas, and produces the most fatal effects. Not long ago upwards of ninety persons lost their lives in the Felling Colliery, near Newcastle, by the combustion of these gasses; and even since that time a second explosion in the same pit has unfortunately added twenty-five more sufferers to the number.

Carburetted hydrogen gas, obtained by heat, from the decomposition of coal, is now very generally employed instead of lamps, in lighting manufactories, and also in lighting the streets of London and some other large towns.

During the spontaneous decomposition that takes place in dead animal or vegetable matter, an impure hydrogen gas is evolved. This frequently takes place in summer time at the bottom

of stagnant ditches of water, so that if a stick be thrust into the mud, the gas is forced out and may be collected at the surface, in an inverted glass of water.

The usual mode of obtaining hydrogen gas for experiment, is from the decomposition of water. If dilute sulphuric acid be poured upon iron filings, the oxygen of the dilute acid combines with the iron and sets the hydrogen free. Hydrogen gas is called inflammable air; but its inflammability is dependent upon the presence of oxygen: If a burning taper be plunged into a jar of this gas it is instantly extinguished by it; but if a portion of oxygen gas be mixed with it, a violent detonation takes place.

Artificial fire-works are formed of hydrogen gas, by inclosing it in a bladder, it is afterwards forced through a fly, and ignited as soon as it begins to escape. The lightness of hydrogen gas particularly distinguishes it from all others. Pure hydrogen gas is about thirteen times lighter than atmospherical air; that which is obtained in the ordinary way is not more than seven or eight times lighter than this air.

Balloons are inflated with hydrogen gas. When a light covering is filled with this gas, and the weight of the atmospherical air displaced, is greater than that of the balloon, it rises in it on the same hydrostatical principles that a cork ascends in a vessel of water.

Dr. Wollaston has pointed out an easy and convenient mode of estimating the relative weight of different gasses, by forming soap-bubbles with them, and observing the time of ascent or descent, according to their respective gravities.

When equal quantities of oxygen and hydrogen gasses are mixed together and ignited, a violent explosion takes place, and the two elements chemically combine and form water. The sound is produced by the collapsing of the atmosphere, from the instantaneous reduction of the oxygen and hydrogen gasses: for the volume or space occupied by water, being above a thousand times less than that of the mixed airs; when the water is formed, the displaced atmosphere rushes together to restore the equilibrium, which produces a violent vibration amongst the particles that compose it.

Although hydrogen gas, in a simple and combined state, is constantly evolved by various processes of art and nature, yet we never find any sensible quantity of this gas, even upon the tops of the highest mountains, or in the more elevated parts of our atmosphere, where it might be supposed that this light air would accumulate. It seems reasonable to conclude, that oxygen and hydrogen gasses mix together, and are chemically combined by the electric fluid which is so frequently seen in the character of lightning darting from a positive to a negative cloud, or

from the cloud to the earth. This may not only account for the descent of rain, but likewise for those peals of thunder which so constantly succeed electric discharges in our atmosphere.

These striking effects may serve to shew the admirable means which nature employs to purify the air from its foreign and noxious ingredients. It is not enough that the gasseous matter should be condensed and returned again to the earth; but it descends in the character of rain to fertilize the vegetable creation, and relieve the wants of man.

Having brought this outline of elementary substances to a conclusion, we cannot do better than extend our views a little further to observe the wisdom of the first cause, and point out the admirable lesson that the laws of nature are constantly presenting to us in every department of her works.

It has been frequently stated that the oxygen gas of our atmosphere is the supporter of combustion, and the indispensable means of preserving animal life. From the immense quantity of this gas that is employed in these two operations only, it might be expected that the oxygen would be constantly diminished until the atmosphere became unfit for the purposes of creation; but this does not happen; we still find the same proportion of oxygen that it possessed on its first analysis, or probably at its first creation.

The unbounded surface of vegetable life affords admirable means for supplying the continued waste; the rich store-house of nature is constantly pouring forth this vital principle, and the diurnal rotation of the earth equalizes it over its surface.

Water is absorbed by the roots of the living vegetable; its elements oxygen and hydrogen, with the carbon obtained from soils and manures, undergo some important chemical changes in the vegetable body; the results of which increase the bulk of the plant, and constitute the peculiar products of the species. But the whole of the oxygen is not employed in these processes; one portion is set free in a gasseous state from the surface of vegetation, by the influence of solar light; this mixes with the atmosphere, and constitutes the important means that nature employs to compensate for the oxygen that is daily destroyed by animal respiration and combustion.

If a small branch of a fresh culled vegetable be exposed to the sun, in an inverted glass of water, gas speedily evolves from the surface of the leaves; this may be collected and examined, and it will be found to be composed of pure oxygen gas; but if the jar be surrounded with black cloth, or shut out from the influence of solar light, no gas can be obtained.

In the economy of nature, it is not enough that oxygen should be supplied for that which has been employed in the processes of combustion

and respiration ; but even these processes produce carbonic acid gas, which is fatal to animals that breathe it; and as its gravity is considerably greater than atmospherical air, it might be expected that the immense quantity which is daily produced, would keep accumulating on the surface of the earth, until the whole creation of animals perished in it.

Here again we are indebted to the vegetable world: from the great avidity which plants possess for the element carbon, we find that a decomposition of carbonic acid gas constantly takes place on the surface of vegetation, and that the carbon enters into combination with the vegetable, whilst the oxygen is poured into the atmosphere.

If a plant be placed in a vessel supplied with carbonic acid gas, it will not only vegetate and thrive, but this gas will gradually disappear, and a portion of free and pure oxygen will be found in its stead.

The foregoing observations explain but a small part of the influence and importance of the vegetable kingdom in the great chain of nature. Vegetation is the connecting link between organized and inorganized bodies, or the direct means which nature employs to convert inert into living matter.

When the vital principle ceases in the animal body, a spontaneous decomposition takes place, which mixes it again with its kindred dust, and

here it would remain for ever in this useless state if it were not again renovated by vegetable influence. A portion of the earthy substance dissolves in water, and through the agency of absorbent vessels, becomes the food of the living plant, and constitutes a part of its body. Animals feed on plants, and plants on earths: thus we perceive the great importance of the vegetable creation, in converting inorganic into living matter, linking together the eternal chain which binds the operations of nature.

CHEMICAL ARTS.

THE alkalis are of indispensable utility in many of the arts. We are indebted to potash and soda for that useful and domestic article, soap. The alkalis are likewise used in glass making, and many other processes. Potash was, till very lately, employed for the important purpose of bleaching.

The alkalis potash, soda, ammonia, barytes, strontian, lime, and magnesia, combine with the different acids, and form a very extensive class of useful salts, some of which are highly important in medicine, as well as in the arts.

Potash and soda are of the most general utility; they were formerly considered as elementary bodies, until they were decomposed by Davy. These two alkalis are generally obtained from the vegetable creation, but they are also found in the animal and mineral world.

The process by which potash is obtained, is to burn the vegetable, and pour water upon the ashes to dissolve the alkali that is contained therein. The clear part of the fluid is then

poured off into a shallow vessel, and heat is applied to evaporate the water, which leaves the alkali behind, in a solid crust, sticking to the sides and bottom of the evaporating pan. This is purified by a second solution and evaporation, and in this state it is called *pearlash*.

Soda is generally obtained from a marine plant, called barrilla, by a process very similar to that of potash. This plant not only furnishes pure soda; it likewise contains a considerable portion of potash; but as potash and soda are both indispensable in soap-making, barrilla is very conveniently employed in this process.

Barrilla is chiefly imported from the shores of the Mediterranean. In Ireland and Scotland they burn sea-weed, and obtain an alkaline mass, called *kelp;* this is composed of potash and soda, but in a very impure state.

An economical mode of decomposing common salt has long been desired; it would furnish this country with an easy and independent mode of supplying its arts and manufactories with soda.

Salt being composed of muriatic acid and soda, the primary object is to detach the soda from the acid, by presenting some other body to the latter, for which it has more chemical affinity than it has for the soda. This may be done by mixing litharge, or oxide of lead, with a solution of common salt; but this process is too expensive at present to render it generally useful.

The alkali *ammonia*, is obtained from animal substances, and consists of the elements hydrogen and nitrogen. It is gasseous in its pure and simple character; but being very absorbable by water, it is generally employed in this state in the arts.

From the difficulty of obtaining barytes and strontian in sufficient quantities, they have not yet been employed for any general purposes in the arts.

SOAP-MAKING. Soap is formed by the chemical union of oil or fat, with potash, soda, and water.

The first step in this process is to prepare a strong *lye*, by pouring water upon a proper proportion of quick lime, mixed with the two alkalis. The lime takes the carbonic acid out of its combination with the alkalis, and renders the fluid caustic, in which state the alkalis have a much greater affinity for the oil or fat.

The lye is now boiled with a quantity of fat, equal to about six times the weight of the alkali employed in preparing it. This operation is continued for many hours, until a curd begins to form; it is then left to cool, and the soap is separated from the water. The soap is now melted and boiled again; it is afterwards poured into proper moulds to cool, and then cut out for sale.

The time which this process takes up is very

uncertain, but generally about six days; the boiling being carried on for about twelve hours each day.

The colour or quality of the soap depends upon the purity of the ingredients employed. White soap is made with the best tallow, and the mottled of an inferior kind. Castile soap is made with vegetable instead of animal oil, and yellow soap has the addition of resin.

The *economic use of soap* for domestic purposes, as well as the arts, is an object of considerable importance, and may warrant a few observations on this subject.

If water and oil be shaken together, they immediately separate from the want of chemical affinity; and as the oil is the lighter body, it forms a stratum on the surface of the water. If the oil and water be shaken up with a solution of alkali, the whole intimately combines, and a saponaceous fluid is produced: if a few drops of dilute sulphuric acid be added, the oil is set free and floats again upon the surface of the water.

When a solution of soap is made in soft water, it intimately combines with the water; but if the solution be made in hard or spring water, a decomposition of the soap takes place, and a curd is seen floating on the surface.

These parallel experiments shew that the acids which are naturally contained in spring water, combine with the alkalis, and decompose the soap,

rendering it to a certain extent useless: therefore, in all cases rain water, which is free from this foreign mixture, is preferable to spring water; but when there is no alternative, spring water may be rendered much more fit for washing, by pumping it up some time before it is employed, and stirring some wood ashes or soda in it, by which the acids will be neutralized and the earths precipitated.

An easy and useful method may be pointed out to ascertain the relative quantity of those substances that usually enter into *spring water*.

The water which is taken up from the surface of the earth, by evaporation, and descends from the atmosphere in the character of rain, is almost pure; but when it falls upon the earth, it keeps sinking through it, until it is collected in fissures, and appears in springs or wells. During its progress, it dissolves many natural salts, and combines with lime and other substances, that give the water particular properties, which depend upon the quantity and quality of the ingredients. These combinations with water are generally sulphuric, muriatic, and carbonic acids, with lime or magnesia, the alkalis, sulphur, and some of the metals.

The presence and relative quantities of these substances are discovered by means of *tests*. We find throughout the whole range of chemical affinity, that bodies have different dispositions to

combine with each other: if we take two that possess a certain degree of affinity, and present a third with a more powerful influence than that with which they combine, a chemical decomposition and recomposition takes place, and frequently produces effects that are sufficient to indicate, in a general way, the relative quantity of the substances concerned.

For instance, the alkali barytes has more affinity for sulphuric acid than any other body; therefore barytes becomes a test for the presence of sulphuric acid, and will detect it when it is combined with any other substance.

A number of other tests are obtained on the same principle, and employed for various other purposes. The test for muriatic acid is nitrate of silver, oxalic acid for lime, gallic acid or prussiate of potash for iron. Suppose a drop or two of muriate of barytes be let fall into a glass of spring water, if the water contains the smallest quantity of sulphuric acid, either free, or in combination with any other body, a white cloud is produced, and the relative quantity of the acid will be determined by its density.

When nitrate of silver is dropped into water, if muriatic acid be present, a yellowish cloud obtains, which has a density according to the quantity of the acid. If lime be present, a light cloud will be formed with a few drops of oxalic acid.

Prussiate of potash is a ready test for iron, by producing a beautiful blue colour, which varies in intensity according to the quantity of iron in solution; but a slice of nutgall suspended by a hair in water for a few hours, is a much more delicate and certain test. When nutgall is employed, it produces a brownish colour in the water, more particularly in that part which immediately surrounds it, and this approaches to blackness according to the quantity of iron in solution.

If copper be present, a few drops of the alkali ammonia produces a beautiful dark blue colour. When sulphur is in combination with hydrogen, it is easily detected by the sense of smelling. Carbonic acid gas is visible in bubbles of slow ascent.

A solution of soap in alcohol is a very useful test to ascertain the hardness of spring water, and its fitness for domestic purposes.

If a few drops of this solution be let fall into rain water, it produces little or no effect; but if it be dropped into spring water, it causes a milkiness, according to the quantity of acid contained in it.

MALTING is a chemical process, derived from that important principle of nature, by which the vegetable creation is perpetuated.

The maltster soaks his grain for a certain number of hours, that it may obtain water, the essential source of vegetable life; it then begins

to sprout, and when this germination has been carried on to a sufficient extent, the process is stopped by drying it; this constitutes malt, the goodness of which depends upon the quantity of saccharine matter that has been produced by the process. If the germination has not been carried far enough, the malt is heavy, but very deficient in saccharine matter. If the germination be carried too far, the malt is light, and the saccharine matter is lost; so that the great object of the maltster is to stop the sprouting by drying the grain, when the greatest quantity of saccharine matter has been produced, and the least taken up in supporting the processes of vegetation.

It is easy to observe the great relation of this process to the sublime operations which nature employs, to give birth to the vegetable creation.

When the seed is thrown into the bosom of the earth, it absorbs moisture, and with the influence of air and heat, those dormant energies are brought forth which may have slept for years. As soon as the grain begins to germinate, the radicle and cotyledons burst from each extremity, and increase in growth until the matured plant produces fresh seed to perpetuate itself.

If we examine the grain before it is sown, we find it composed of nutritive and mucilaginous matter, without any saccharine or sugary taste: but if we dry some of the grains when they have

lain in the earth, until the process of germination has taken place, it will be found that they possess a decided sweetness, and contain a saccharine substance, the quantity of which entirely depends upon the extent of germination.

It appears evident, in this case, that the principle of life, with the assistance of light, heat, air, and water, converts the substance of the seed into saccharine matter for the support of the infant germ, until the tender root has sufficient strength to lay hold of the earth, and derive its support from this common source. When the plant has obtained this point, the original seed may be examined, and we shall find nothing remaining but the husk and a watery fluid.

In the processes of BREWING and WINE-MAKING, the first object is to obtain a solution of the saccharine matter that is contained in the ripe fruit, or malt, and subject it to a spontaneous process, termed the vinous fermentation; by which the elements of sugar and water undergo a chemical change, and combine in different proportions, to constitute alcohol, water, and carbonic acid gas.

If an infusion of malt; the expressed juice of grapes, or any other saccharine fruit, be left undisturbed, at a certain temperature, an intestine motion spontaneously takes place, the fluid becomes turbid, the heat increases, and a quantity of carbonic acid gas is evolved from the surface.

When the operation ceases, it is found that the fluid has changed its qualities; we have no longer sugar and water, but an ardent, stimulating and intoxicating fluid, called alcohol, united with water, and a small portion of saccharine matter, which still remains in solution. In a stricter view, there are many other products in the beer or wine that is thus formed, such as acids, alkalis, earths, colouring matter, and essential oils.

Alcohol, like sugar and water, is composed of the elements, oxygen, hydrogen, and carbon; but the quantity of oxygen and carbon which it possesses, is less than that contained in the saccharine fluid, by the quantity of oxygen and carbon that has been employed in constituting carbonic acid gas, during the process of fermentation; so that this chemical or electrical process consists only in changing the quantities of the elements employed, and affords a striking proof how much the properties of bodies are dependent upon electricity, rather than upon their elements.

The flavour of different wines is the result of vegetable secretions; these are so obscurely effected in the chemical elaboratory of vegetable life, that the utmost exertion of the human mind, with all its happy propensity to theorize, has never been able to hazard a rational conjecture on this head.

The generality of these secretions are volatile,

and of an oily or resinous kind, which are indifferently soluble in water, but readily unite with alcohol.

The operation of DISTILLATION is to separate the alcoholic or spirituous, from the aqueous part.

The specific gravity of alcohol to water is as eight to ten. Alcohol boils at the temperature of one hundred and seventy-six degrees; but water will not boil until it obtains a temperature of two hundred and twelve degrees; so that the chief object of distillation is to keep the heat above one hundred and seventy-four degrees, and less than two hundred and twelve. In this case the alcohol rises from the water in the boiler in the character of steam or vapour; is condensed in passing through a long spiral tube, surrounded by cold water, and drops from the extremity a colourless, inelastic fluid, consisting of alcohol and essential oil, or flavouring matter, in solution.

If beer or wine be exposed to the atmosphere in warm weather, another chemical process takes place, which converts it into *vinegar*. This process is called the acetous fermentation.

If a barrel half filled with wine or beer, be exposed to the sun's rays in summer, an intestine motion soon takes place; the temperature increases, and the fluid becomes turbid, evolving a disagreeable smell. During this change the oxygen gas of the atmosphere is greedily absorbed,

and the liquor has its acidity accordingly. This points out the disadvantage of filling barrels to the bung-hole in the process of vinegar-making; when the surface is considerable, it affords more ready means for the absorption of oxygen.

What is called Must, or mother vinegar, is a highly oxygenized state of the fluid; and like barm or yeast in the vinous fermentation, gives great facility to the commencement of the acetous process.

The three operations of bleaching, dying, and calico-printing, are very dependent upon each other; for bright colours can never be obtained without good bleaching, and calico-printing is but a partial mode of dying. Our immense manufacture of printed cotton for exportation and home consumption, affords an unequivocal proof of the importance of chemical arts to a nation like this, that owes its pre-eminence to its unbounded commerce.

The object of BLEACHING is to remove or decompose the dark colour which thread, or manufactured goods derive from the natural state of flax or cotton.

The usual mode, till within these few years, was to steep the fabric in a solution of potash, and expose it in the bleach-field to the decomposing influence of light and the atmosphere.

The addition of the diluted alkali serves to abstract the oxygen from the atmosphere more

readily; but this process of whitening is so slow that it frequently requires many weeks to complete it, and the same object is now obtained in as many hours by the new method.

Scheele discovered that oxygenated muriatic gas decomposed the colour of flowers and other vegetables; but Bertholet, a French chemist, was the first that applied it to the modern mode of bleaching.

The cloth which is to be bleached, is soaked in water for about twenty-four hours; it is then passed through an alkaline lye, and afterwards well washed. In this state it is brought into the bleaching liquor and left for three or four hours; after this it is again passed through the alkaline solution, and returned to the bleaching liquor for half an hour more; and these processes are repeated four or five times, or until the object is obtained.

In the commencement of this modern practice of bleaching, it was found that the muriatic acid attacked the vegetable fibre, consequently, damaged the cloth. This inconvenience is now removed, by employing a solution of oxymuriate of lime instead of oxymuriatic acid. In this case the muriatic acid combines with the lime, which prevents it from acting upon the cloth. Davy has recommended an oxymuriate of magnesia for the same purpose.

Prejudice still exists against the modern mode

of bleaching; but this is the only difficulty to be overcome; the practice has now been general for some years, and although many of the retail venders of linen cloths pretend to favour the objections that are brought against this modern mode, by stating that they are bleached on the grass, it is only to serve a pecuniary object, which is generally obtained at the expense of truth.

Oxygenated muriatic gas is the pure state of the bleaching principle; but this gas is rapidly absorbed by water, and in this state it constitutes oxygenated muriatic acid. When this acid is combined with lime, it forms oxymuriate of lime.

If dilute sulphuric acid be poured upon a mixture of manganese and common salt, it combines with the soda of the salt, and detaches the muriatic acid, which uniting with the oxygen afforded by the manganese, constitutes oxymuriatic gas.

This gas is not only the fundamental principle of bleaching, but is found the most useful in purifying the air of rooms that are rendered unhealthful by the decomposition of animal matter.

A small portion of this gas may be usefully employed in purifying rooms after contagious diseases.

If muriatic acid be poured upon oxymuriate of potash, in a wine glass, a sufficient quantity of

gas is obtained for this purpose; and it is not even necessary to remove the patient out of the room.

Sir H. Davy supposes that oxymuriatic gas is not formed of muriatic acid and oxygen, but composed of an element hitherto unknown, which he calls chlorine, united with vapour; and that muriatic acid is formed of chlorine and the hydrogen of the vapour, when the oxygen is taken up in the process of bleaching, or in supporting combustion in this gas.

The art of DYING is of great antiquity; and the clothing of the mummies sufficiently proves that the Egyptians possessed it in no inconsiderable degree. The high estimation of Tyrian cloths, also shews that the Phœnicians were not inferior in this practice; for their scarlet and purple cloths were sought after by every civilized nation, and greatly enriched the city of Tyre, until the folly and vanity of some of its tyrants destroyed its commerce, by issuing an edict that prohibited the cloths from being worn by any, except themselves and their great officers of state.

In England, the art of dying made no progress until the commencement of the seventeenth century. Previous to that time, the English cloths were generally sent to Holland to be dyed.

As we have every reason to believe that chemical science is of very late origin, so we may fairly suppose that the early art of dying was

much more dependent upon chance than upon any principle of science. The present state of this art has all the advantages of chemical knowledge; but still there are many obscurities in the practice which are yet to be removed.

The three original colours of dyers, are *red, yellow,* and *blue;* some add *brown* and *black;* but the two last can only be considered as privations of colour.

The substances which contain colouring matter, and are used in dying, are chiefly of the vegetable kingdom; sometimes mineral products are employed, which are generally oxides of iron, tin, or copper.

The colouring drugs of dyers may be divided into *three classes.*

First. Those substances which contain extractive, earthy, and resinous matter.

In this class the colouring principle has a strong attraction for the earth, and the earth for the substance to be dyed; so that a separation of the colouring matter from the water is easily effected, and the colour combines with the fabric, without the necessity of a base or mordant. Galls and sumach are vegetable products of this description.

Second. Those bodies that are composed of extractive matter, but are deficient in the earthy principle.

To communicate the colouring matter in this

case, it requires an earth to be previously introduced into the pores or interstices of the substance to be dyed, so as to form a basis, to which the colour may adhere.

The attraction of the colouring matter for the fabric, without this medium, is so weak as not to be able to separate it from the water, or being separated, to retain it, or prevent it from being dissolved by the action of soap in the operation of washing. Peach and Brazil wood are of the second description.

Third. This class consists of colouring matter, so completely resinous that it cannot be communicated without some chemical agency to promote its solution in water. This solvent is either an alkaline salt or quicklime; but the latter is the most frequently employed.

Indigo and arnatto are resinous substances of this kind. When these bodies are decomposed, they will combine with the fabric without the necessity of a mordant or base.

Alumina, or an oxide of tin, constitutes the base which is generally employed in the process of dying; the former is the most frequently used.

Alumina, or the earthy part of alum, has a strong attraction for colouring matter, particularly for such as form red and yellow colours. If a solution of alum be poured into water, deeply tinged with these colouring substances, the

alumina will quit the sulphuric acid with which it combines, and unite with the colouring matter; producing a sensible mass that will resist the action of water or alcohol.

When tin is dissolved in acids it has a strong attraction for colouring matter, and is, in some cases, preferable to alum.

If a few drops of muriate of tin be added to a solution of cochineal, in water, it combines with the colouring matter, and forms a beautiful precipitate, well known by the name of carmine.

If a piece of cloth which has been previously prepared by boiling in alum and water, be introduced into a vessel of boiling water, containing a small portion of Brazil or peach wood, the colouring matter will speedily combine with the fabric, through the intervention of the alumina, and obtain a beautiful and permanent red. If a piece of unalumed cloth be put in at the same time, it will come out merely stained with the colouring matter, and this may be readily discharged by boiling the cloth in bran and water, or exposing it in the bleach field.

Some of the colouring substances that are employed in dying yellows, contain a sufficient quantity of earthy matter to render bases unnecessary; but these frequently form what is termed a fugitive colour, which becomes decomposed by the influence of solar light.

If a piece of cloth be boiled in water with

turmeric or American bark, the colouring matter will combine with it ; but this will be rendered more permanent with an alumed base.

To dye blue, take one part indigo, and reduce the solid mass into a smooth unctuous substance with water ; when this is sufficiently diluted, add three parts of pulverized lime, and two of sulphate of iron ; the whole is suffered to combine for two or three days, taking care to stir it up frequently.

This operation, which is a fermentative process, decomposes the beautiful blue colour of the indigo, and produces a dark green.

In this case the sulphuric acid of the salt combines with a portion of the lime, and suffers a deoxidizement of the colouring matter by the iron ; and another portion of the lime combines with the resinous substance of the colouring matter, and promotes its solution in the water.

When the fabric to be dyed is introduced into this prepared menstruum, the colouring particles combine with it, and it obtains a fine green ; but as soon as it is taken out of the fluid, the colouring matter rapidly attracts the oxygen of the atmosphere, and the colour of the fabric is gradually converted from a dark green into a beautiful and permanent blue by this oxidizement.

Browns and blacks are produced by different proportions of sulphate of iron, and the astringent principle, or tincture of galls. Logwood contains

the astringent principle, and is generally employed in dying black.

If the substance to be dyed be previously boiled in sulphate of iron, it becomes black when it is introduced into the tincture of galls.

All the different colours, and the various shades of each colour, are produced by the different combinations and modifications of what has been termed the primitive colours of the dyers.

CALICO-PRINTING is a process so similar to dying, in point of theory, that it is scarcely necessary to do more than give a detail of some of the mechanical practice.

The operation of dying communicates one general colour to the fabric; but the art of calico-printing consists in communicating more colours than one, and these in regular arrangement, according to the pattern employed.

When a base is used in dying, the whole of the fabric is immersed in it; but in calico-printing the base is partially communicated, and only received by those parts that are intended to be affected by the colouring matter.

Another thick fluid, called a resist, is used in calico-printing, which is communicated to the cloth by a pattern, and prevents the combination of colour in one dying bath, that it may be impregnated in another.

The different bases and resists are chiefly composed of alumina, or the metallic oxides in

solution, thickened and brought to a proper consistence with flour.

After the cloth has been well bleached and calendered, it is then ready to receive the pattern or outline of the design.

In the first instance the design is drawn upon paper, and afterwards copied upon a block of wood, about twelve inches square. It is then cut out upon the flat surface of the wood, or brassed, as it is termed. The latter operation consists in driving small slips of copper into the face of the block, according to the outline of the pattern: the other process raises the pattern on the wood, by cutting away the unnecessary part of the surface.

When the block is completed, the outline of the pattern is communicated to the cloth with a black ink, prepared from a strong infusion of nut-galls and a nitrate or acetate of iron, thickened with flour.

The cloth which is to be printed, is stretched evenly over a flat surface, and the printer takes a portion of the ink upon the block, from a sieve or cushion, and transfers it to the surface of the cloth by a smart blow on the back of the block; this is continued until the whole of the cloth is covered.

The next process consists in grounding the outline, or filling up with a base those parts of the pattern that are intended to receive the colouring

matter. This is effected by another block of wood, so cut out that the remaining parts of the surface of the block may just fill up the figure of the outline; the block is dipped into the base, and then carefully communicated to the parts of the pattern that are intended to receive it. If the figure is to consist of different colours, or shades of the same colour, each is communicated by a distinct block and different bases, according to the nature of the colour.

When the outline and ground are sufficiently dry, the paste or thickening matter is washed out, and the fabric is then ready for the dying bath; for the bases remain chemically combined with the fibre of the cloth. As soon as the cloth has obtained a sufficient intensity of colour, it is withdrawn and thoroughly washed in cold water. If the colouring matter has affected the white ground more than the water can remove, the fabric is boiled in bran and water for some time, and then stretched out in the bleach field, which soon renders it perfectly white.

GEOLOGY.

THE subject of geology comprehends the structure, composition, and arrangement of the materials which form mountains or rocks. It likewise includes the mineral beds and metallic veins by which the rocks and strata are intersected.

The opinions of Geologists have been very much divided respecting the means that nature has employed in effecting the constitution and various changes of the earth; but this will not excite our surprise, when we consider that the fabrication of a world, or the means of arrangement amongst its parts, were never intended to form subject matter for the finite capacity of man: it is enough for him to examine the laws that are constantly operating upon its surface, and render them useful to society.

Hutton supposes that primary or chrystalized rocks were formed from the materials of a more ancient world, fused by subterranean and central heat; and that secondary strata were formed from the decayed materials of former continents carried down rivers, and deposited at the bottom

of the sea. These substances being at a greater distance from the central heat, were imperfectly fused, or merely softened and consolidated, without losing their stratified structure. Hutton also supposes that the present continents have been raised from the ocean, by the expansive power of subterranean fires, which have bent, fractured, and separated the incumbent strata, and elevated the subjacent rocks.

On the other hand, Werner supposes that all the superficial parts of the globe were once in a state of aqueous solution, and that primitive substances were separated by chemical deposition in a chrystaline state, which formed a thick mass of granite round the nucleus of our globe.

In the process of time, other layers of what are termed primary rocks, were successively deposited from the dissolved mass. From subsequent changes, transition rocks were laid upon the primitive; and lastly, stratified rocks were laid upon the transition, constituting the present formation, or mineral arrangement of the earth.

Whilst these operations were going on, the original waters were gradually retiring and became turbid, which rendered the deposited matter that formed the upper strata, more earthy and less chrystalized than that of the primary rocks. The more recent formations were intermixed with fragments that were broken off and worn away from those rocks that had been previously

formed. Werner also supposes that mountains and vallies were produced by the original inequality of the nucleus of the earth.

Such is the outline of the two prominent theories of the present day; each has its strenuous advocates, and the great question is, whether fire or water has been most concerned in the constitution and arrangement of the parts that compose our earth. If we look with an unprejudiced eye upon the various mineral productions and arrangements that are presented us, we may fairly suppose that both have been concerned. Why may we not as reasonably admit the influence of fire and water in explaining the intricate phænomena of the subject of geology, as to suppose the whole to be resolved by the agency of either one or the other.

As the Wernerian system is the most generally received, the following observations will more particularly embrace these opinions.

According to Werner, the upper part of the earth, as far as it has been penetrated or observed, is divided into a *primitive, transition, floetz, volcanic,* and *alluvial formation.*

The PRIMITIVE FORMATION does not contain any vestige of organic remains; it is therefore supposed that rocks of this description were formed prior to the creation of either animals or vegetables. These rocks are extremely hard, and are composed of a chrystaline substance;

they form the lowest part of the earth's surface with which we are acquainted, and they not only constitute the foundation of other rocks, but in many situations, they pierce through the incumbent strata, and frequently form the highest mountains in alpine districts.

When we see a range of mountains bounded by a plain, we are not to conclude that they terminate at their apparent bases; for they frequently dip under the surface of the earth, at angles more or less inclined, and rise again, in remote districts, to a considerable height above the general surface.

TRANSITION ROCKS are supposed to have been formed when the world was passing from a chaotic to a habitable state; these rocks are less chrystalized than the preceding division, and contain organic remains of zoophytes, or those animals which are considered as the lowest link in the chain of animated beings.

Primary and transition rocks are the principal repositories of metallic ores; the more recent formations contain abundant remains of animal and vegetable bodies.

The FLOETZ FORMATION is still less chrystalized than the transition; indeed it may be considered as the effect of a mechanical aggregation of the detrition or abraided substances of earlier formations, cemented by the influence of calcarious and aluminous earths.

The floetz division likewise contains independent

beds of stratified sand-stone, coal and lime-stone; and water-worn fragments of other rocks, which evidently shew that this formation has been constituted at a later period than all the rest.

VOLCANIC PRODUCTS are formed of those substances which are ejected from volcanos, by the agency of subterraneous fires: these products are frequently found to constitute islands where volcanic irruptions were never known, and most satisfactorily prove the great convulsions that have taken place at different times on the surface of the earth.

The ALLUVIAL FORMATION is the most recent, and may be considered as undergoing constant changes, from the decomposition and recomposition of animal and vegetable substances on the surface of the earth. It consists of land formed from the detrition of rocks by the agency of water; and in upper situations it consists chiefly of gravel, sand, and clay; in lower districts, of a more loamy soil.

These geological divisions have been pointed out, by referring to the mineral arrangement of Great Britain.

On the east side of a line extending from Dorsetshire to Scarborough, in Yorkshire, the whole district is composed of chalk, calcarious lime-stone, or alluvial ground, in which no workable coal or metallic veins occur. This constitutes the last or floetz formation.

On the coast of Lincolnshire, and part of Yorkshire, there is a subterranean forest, about seventeen feet under the present high water mark, and which appears to extend into the sea, as the stumps and roots of trees may be distinctly seen at low water.

An older floetz forms what may be termed the middle district, which is bounded on the east by the line already mentioned; and by part of Cornwall, Wales, and Cumberland, on the west. This formation differs very considerably from the preceding, as it contains beds of iron-stone, and coal; and towards the northern part of England, are mountains of metalliferous lime-stone.

The transition and primary mountains are arranged along the western side, and are rich in metallic ores; they constitute the alpine part of England, extending through Cornwall and Devonshire, into Wales and Cumberland; and from thence to the northen part of Scotland.

The fossil remains of animals, entombed and preserved in solid rocks, present us with durable monuments of the great changes which our planet has undergone in former ages. Even in the southern counties of England, the bones of the Rhinoceros, Elephant, Crocodile, Mammoth, and species of other animals, which no longer exist, have been discovered in thick beds of clay.

From productions of this description, we must admit of one of the following conclusions, either

that the sea has retired and sunk below its former level, according to the Wernerian hypothesis; or, with Hutton, that some power operating from beneath, has lifted up the islands and continents, with all their hills and mountains, from the watery abyss, to their present situation above its surface; whichever may be the operating principle, it is most evident that great revolutions have been effected, and apparently, at very different times.

The inundations, or convulsions which buried vegetables and quadrupeds in distinct strata, were subsequent to each other, and both posterior to the formation of primitive lime-stone; as this rock is never found to contain any organic remains. It is supposed, by Hutton, that man was created at a much later period than brute animals, or vegetables; as human bones are never found even in the rocks of the latest formation. This, however, is not strictly correct, as a human skeleton has recently been found mineralized in a floetz rock, in the island of Guadaloupe, and is now deposited in the British Museum.

Geologists divide the general structure of rocks, which form mountain masses, into *stratified*, *tabular*, *columnar*, and *globular*.

The *stratified* mountains are those which are composed of layers or plates of stone, separated by parallel seams, and have different degrees of inclination.

The *tabular* structure consists of tables, or plates, which have generally a vertical direction.

The *columnar* is peculiar to certain rocks of the basaltic kind.

The *globular* form consists of balls of different sizes, sometimes detached, and at others imbedded in rocks of the same kind.

However numerous the varieties of rocks or stones may be, the *elementary principles*, in general terms, may be reduced to the four earths, *lime*, *magnesia*, *silex*, and *clay*, and the *oxide of iron*. To these may be added *barytes*, *strontian*, *yttria*, and *zircone*; but these solid substances are very sparingly distributed.

Simple minerals are formed by the combination of the first four earths, in different proportions, and compose primary rocks.

These minerals are *quartz*, *felspar*, *mica*, *talc*, and *hornblende*.

The *rocks of* PRIMITIVE FORMATION are *granite*, *gneiss*, *mica-slate* and *clay-slate*.

Granite is the lowest of all the formations, and the basis on which the others rest; it is composed of felspar, quartz, and mica, each in a chrystalized state, and united without any cementing body.

Granite is not so rich in metals as some other rocks; the ores of tin and iron are the most abundant.

The granite rock is not stratified, it is in general exceedingly hard, and admirably calculated for monuments that are intended to resist the destroying arm of time. Some granitic rocks are

found to contain a portion of potash, which disintegrates or produces a continual decomposition on their surface. Some of the granite rocks on the western side of Cornwall, are of this description.

Gneiss lies over the granite, and is constituted of the same elements, but differs in its structure, being stratified or disposed in plates from the prevalence of the mica.

Mica-slate lies immediately over the gneiss: this rock differs in its composition from the two preceding, being composed of quartz and mica, without felspar.

Mica-slate passes into *clay-slate*, which is always stratified, and occasionally contains chrystals of felspar and hornblende.

Beds or *patches* of limestone, and other rocks, are found dispersed amongst the strata of primitive mountains.

The TRANSITION is the second formation, and consists of rocks of *greywacke, transition limestone, transition trap,* and *transition flint-slate.*

These rocks alternate with each other, without any regular order, except the transition limestone, which always rests on the primitive formation, and may therefore be fairly considered as the oldest of the transition formations.

Greywacke is a rock composed of pieces of quartz, flint-slate, felspar, and clay-slate, cemented together by a basis of clay-slate. Greywacke rocks are generally rich in beds and veins of ores:

the veins are frequently of a peculiarly large magnitude.

Transition limestone is a simple rock, which contains marine petrifactions of corals and zoophites, which no longer exist, and which do not occur in the subsequent limestone formations: these beds frequently contain an abundant quantity of metallic ores.

Transition trap rocks are distinguished by the great proportion of hornblende which they contain: the common clay iron-stone occurs in this rock.

Transition flint-slate chiefly consists of common flint-slate and lydian-stone, which pass into each other, and is characterized by containing many veins of quartz.

All the rocks of the transition formation are in a state of much less perfect chrystalization than those of the primitive.

The FLOETZ is the latest of the formations, and appears to be composed of fragments or particles of rocks from the preceding formations, worn away by some great convulsion of nature, and cemented or agglutinated by the attraction of cohesion, without the least chrystaline arrangement. This division of rocks has received the German name of floetz, because they lie in beds much more horizontal than the preceding classes. Floetz rocks contain abundance of petrifactions, which are much more various in their nature

than those that occur in the transition formation: they consist of shells, fishes, and plants, which indicate that these rocks were formed at a period when organized beings abounded.

The floetz formation lies immediately over the transition; it comprehends a great number of individual formations, each of which is arranged in a particular situation, as follows: *Old red sand-stone; first floetz lime-stone; first floetz gypsum,* with *rock-salt; variegated sand-stone; second floetz gypsum; second floetz lime-stone; third sand-stone,* or *free-stone; chalk; independent coal,* and *floetz trap.*

Old red sand-stone lies immediately over the transition rocks; hence it is considered as the oldest of the floetz formation: it is composed of grains of quartz, or some other silicious stone, cemented together by a base, and can only be considered as a mere mechanical mixture, united by the influence of cohesive attraction. The cementing principle is sometimes clay, quartz, or lime, and the rock is accordingly named argillaceous, silicious, or calcareous sand-stone.

First floetz lime-stone is usually of a grey colour and compact fracture; it has no lustre, and is only translucent on the edges. This formation is well characterized by the masses of horn-stone and flint which it contains: the bed is always contiguous to the sand-stone, and contains but few petrifactions, and these are chiefly fish.

First floetz gypsum takes the next position, and consists chiefly of compact gypsum, together with selenite. Swine-stone, and rock-salt, belong to this formation.

Variegated sand-stone consists of fine granular argillaceous sand-stone, usually of a green, brown, red, and white colour; several of these alternate in stripes, which gives the stone a variegated appearance.

Second floetz gypsum lies over the preceding, in beds; it contains foliated gypsum, but scarcely any selenite, and no swine-stone; it is characterized by its fibrous appearance. This formation is of no great extent, and like the first gypsum, is destitute of petrifactions.

Second floetz, or *shell lime-stone,* is known by the vast number of shells which it contains in the state of petrifactions.

Third sand-stone, or *free-stone,* is mostly of a white colour, and well adapted for building: it is usually stratified, and contains natural rents or seams, which cross each other at right angles; the one parallel to the stratification, and the other perpendicular to it; so that it can easily be quarried into large blocks; this is a character that belongs generally to sand-stones.

Chalk is one of the newest floetz rocks; it is generally found near the sea, and contains numerous beds of nodular flint, often full of vessicles. This formation is distinctly stratified

and forms hills of a small height. Pyrites are sometimes found in it; but scarcely any other metallic ore.

Independent coal formation is deposited in detached patches usually in vallies, over the preceding floetz rocks, or over the transition rocks, when the floetz are wanting.

These patches have in general no connexion with each other; it is on this account that they are called independent. In this formation coal is very abundant. Besides coal, this formation includes rocks of *sand-stone, coarse conglomerate slate-clay, bituminous shale, indurated clay, lime-stone, marl, gypsum, clay iron-stone, porphyritic-stone,* and *green-stone.*

Layers of these rocks alternate a great many times with each other, and the coal occurs in them in numerous beds, varying greatly in thickness.

The rocks belonging to this formation are distinctly stratified, and abundance of petrifactions are found in them, particularly in the sand-stone, and bituminous shale, and clay iron-stone; these are chiefly vegetables, of which ferns and reeds are the most common. They are rather casts than real petrifactions that are found in the sand-stone; many specimens appear to belong to the tribe of palms, but none of them can be referred to any known species.

Alluvial formations constitute the great mass

of the earth's surface, which has been formed by the gradual action of rain and river water upon the other formations, and may be considered as a deposit which is constantly going on.

Alluvial formations are of two kinds; those deposits which are formed in the vallies of mountain districts, or upon the elevated plains which frequently occur amongst mountains; and the deposits upon flat land in low districts.

The first consists of gravel, sand, and other substances that previously constituted the more solid parts of the neighbouring mountains, but which have been worn away by the continued action of rain and other atmospherical influences. This deposit frequently contains metallic ores, particularly gold and tin, which have been washed down from their native beds in the neighbouring mountains.

The second kind of alluvial earth is that which occupies the flat districts, and consists chiefly of loam, clay, sand, and turf. The clay and sand of this formation frequently contain petrified wood and skeletons of quadrupeds.

Volcanic formations are of two kinds, one called pseudo volcanic, and the other true volcanic.

The pseudo volcanic consists of minerals, altered in consequence of the burning beds of coal situated in their neighbourhood. *Porcelain jasper, earth slag, burnt clay, columnar clay iron-stone,* and *polishing slate* are minerals that have been thus altered.

The real volcanic minerals are those which have been thrown out of the crater of a volcano. They are of three kinds.

First, Those substances which have been thrown out from time to time, and have formed the crater of the mountain. Secondly, Those which have been thrown out of the crater in a state of fusion, and rolled down the mountain, which constitute lava. Thirdly, Ashes and other light substances, that are termed volcanic tuffa.

MINERALOGY.

METALLIC ores, which are the object of the miner's labour, are obtained from *beds* and *veins;* but in this country more frequently from veins.

In mountainous countries where the hills are high and conical, and their sides precipitous, the metallic ores are frequently found in *beds;* but where they have less acclivity, and are more undulating on their surface, the metals are found deposited in *veins,* which cut through the general strata of the mountain, and are filled with substances more or less different from the rocks that they pervade.

We may form some idea of veins, by supposing a mountain shaken or split by some great convulsion, and that the rifts thus formed were filled up by the matter which constitutes veins. They are distinguished from the more horizontal position of beds, by their direction, which is either perpendicular to the stratification, or forming an angle with it.

It frequently happens that the strata through which veins pass, are merely separated by them,

so that on cutting through the vein, the same stratum is found on each side of it. Sometimes the corresponding strata on one side are lower than on the other, as if the rock had sunk a little from its original position on one side of the vein; this, amongst miners, is called a shift.

Mineralogists generally agree in representing the veins widest at top, and gradually diminishing in size, downwards. Veins, or chasms, are occasionally found in the bowels of the earth, entirely empty; but they most commonly contain substances very different from the strata through which they pass. And these masses are frequently deposited in regular layers parallel to the sides of the vein; possessing a wedge-like form, with the same mineral strata corresponding on each side.

Almost every mineral substance which occurs in the general mass of rocks, has been found in veins. It is not uncommon to meet with granite, lime-stone, porphyry, and basalt or greywacke, green-stone, quartz, clay, and felspar; even pit-coal, common salt, water-worn pebbles, loam, and petrifactions have been occasionally met with.

The *chrystalization* of different minerals varies; even the same mineral does not always assume the same form. If the chrystalization of the mineral was constantly under the same circumstances, the arrangement of its particles would

probably be the same; but the least variation in circumstance makes a consequent variation in position: it is on this account that some difficulty has been found in ascertaining the specific form of different minerals.

This subject has recently received great advantages from the splendid talents of Haüy, who has traced the *primitive form* of every chrystaline substance to some of the six regular bodies which follow:

1st. The cube, or rhomboidal parallelopipedon.

2d. The octahedron.

3d. The tetrahedron.

4th. The hexhedral prism.

5th. The dodecahedron of twelve rhomboidal surfaces.

6th. The dodecahedron of two six-sided pyramids, applied base to base.

Although different chrystals of the same substance occasionally vary in figure, yet the primitive form of the chrystals is constantly the same.

Some primitive forms are divisible into planes that are not parallel to their surfaces; when this is the case, a solid figure is obtained, which differs from the primitive form of the chrystal to which it belongs.

This, according to Haüy, is called the *integrant molecule*, and it possesses three different forms, namely, the *tetrahedron*, *triangular prism*, and *parallelopipedon*.

Every chrystal is made up of a vast number of these integrant molecules, and the different varieties of chrystals are produced by a variation in the arrangement of these primitive or original forms.

The ELEMENTARY EARTHS, *lime, magnesia, barytes, strontian, alumina, silex, yttria,* and *zircone,* united in different proportions, and occasionally mixed with metallic substances, containing oxygen, arsenic, or sulphur, compose the greater and smaller masses that constitute our globe. These earths blended and combined with native acids, form a beautiful assemblage of amorphous and chrystalized minerals, which it would be tedious and uninteresting to describe to any great extent, without being able to refer to the specimens themselves.

The different *combinations of lime* constitute a very prominent mass upon the surface of the earth. Lime united with carbonic acid, exists in abundant quantities, and comprehends lime-stone, chalk, marble, and calcareous spar.

The immense calcareous masses that form a considerable part of the shell or crust of our globe, appear to owe their origin to an aggregation of shells, which are plentifully found in a perfect but mineralized state upon the summits of some of the highest mountains. This circumstance alone must satisfactorily prove the very important changes which this planet has undergone at different times.

The term *marble* is generally applied to limestone when it is hard enough to receive a polish. The south-coast of Devonshire, Wales, Ireland, and Westmoreland, afford a great variety of handsome specimens; but still they are not equal to the Italian or Grecian marble.

Carbonate of lime chrystalizes and forms a beautiful class of minerals for the cabinet. Rhombs constitute the most usual form of the chrystals.

Stalactites, which are formed of carbonate of lime, are those concretions that are found hanging from the roofs of caverns. When water holding lime in solution, enters the cavern, the drop keeps accumulating until it falls by its own gravity, leaving some portion of the calcareous particles sticking to the roof: this is succeeded by another drop, which again deposits an additional portion, and thus the mass keeps gradually increasing until the stalactite obtains a considerable magnitude. This process is, without doubt, greatly facilitated by the carbonic acid gas that is so prevalent in caverns. When the water which holds lime in solution enters, the lime combines with the gas, and instantly forms a solid mass. It frequently happens that another mass of sub-carbonate of lime, is formed on the floor of the cavern, by drops of lime-water that fall from the extremity of the stalactite; this is called a stalagmite. The

extremities of the stalactite and stalagmite frequently keep approaching each other, until they join and form a beautiful column of chrystalized carbonate of lime.

Stalactic incrustations are well known by the name of petrifactions. When water that is impregnated with calcareous matter remains long in contact with vegetable bodies, they obtain a stony incrustation; and being of a perishable nature, a portion of the substance keeps continually decaying, which is regularly filled up by the lime, until, at length, the whole mass is converted into calcareous spar. The dropping well at Knaresborough, in Yorkshire, like many others of a similar description, produces these calcareous incrustations in a very short time.

When lime contains a sufficient quantity of clay to crumble to pieces by exposure to the atmosphere, or to fall into powder, under water, it is called *marle*. The quantity of lime to the clay is about three or four to one: this may be easily determined by decomposing the marle with sulphuric acid, which takes the calcareous earth out of its combination with the clay.

When marle contains a superior quantity of lime, it is generally employed with advantage in clayey soils, rendering them higher and more capable of division, by the usual processes of agriculture. On the other hand, in sandy loose soils, that marle is preferred which contains the

greatest quantity of clay, by giving more strength and consistency to the earth.

Sulphate of lime is formed of sulphuric acid and lime; from the abundant quantity that has long been obtained from a quarry in the neighbourhood of Paris, it is commonly called plaster of Paris.

Plaster images are formed by mixing the calcined powder with water, and afterwards pouring the mixture into moulds.

Sulphate of lime, in its amorphous state, is called gypsum; when it is chrystalized, it is called selenite.

Fluate of lime, or *fluor spar,* is formed from the combination of a peculiar acid, called the fluoric acid, with lime. The mines of Derbyshire, Cumberland, and Cornwall, afford an abundant quantity of chrystalized fluor, which is remarkable for its regular form, beautiful colours, and sometimes for its transparent appearance.

The colour of fluor spar is chiefly derived from iron; but copper, cobalt, and other metals sometimes enter into its composition. The colour of the spar is modified and changed by heat, and the manufactured fluor is generally subjected to its effects, which converts the blue to reddish purple, brown, and different shades of yellow; but the artificial are much inferior to the natural colours.

Although the fluoric acid is not corrosive like

other acids, it possesses the remarkable property of dissolving glass and other silicious substances. The acid is obtained by condensing the vapour which is produced by heating fluor and sulphuric acid in a leaden bottle.

Barytes. We are indebted to Scheele and Bergman for the knowledge of this earth: it is always found in combination with sulphuric or carbonic acid; but the sulphate is much more plentiful than the carbonate of barytes. This mineral is a virulent poison.

Strontian. This earth obtained its name from strontian, in Argyleshire, where it was first discovered; it has since been found on the Continent, in the neighbourhood of Bristol, and some other places; but it is still much less plentiful than barytes: like the latter mineral, it has only been found in combination with sulphuric or carbonic acid. The carbonate is obtained from strontian, and the sulphate from the neighbourhood of Bristol.

Magnesia has never been found disengaged from foreign substances: the generality of the earthy bodies into which it enters have a striking character, and are easily known by being greasy and soft to the touch. Magnesian substances may be readily cut with a knife, or turned in a lathe, and take a good polish. Bodies containing magnesia adhere to the tongue like clay, but do not soften in water; they have likewise a fibrous texture and a greenish colour.

Magnesia, silex and iron, constitute a rock, called serpentine, which forms the Lizard Point, in Cornwall; the predominate colour is a very dark green, which sometimes inclines to brown.

A very beautiful serpentine is obtained near Pary's Mountain, in the Island of Anglesea; this is now fabricated into chimney-pieces and other household ornaments, under the name of Anglesea marble; but it is more durable than marble, as it does not lose its polish by being exposed to the influence of acids.

Amianthus is composed of magnesia, silex and alumina; the magnesia forms about a quarter of the substance. From the great infusibility and fibrous character of amianthus, it was formerly mixed with flax, and woven into a kind of cloth, with which the ancients inclosed the bodies of the dead, that the ashes might be preserved in the covering after they were burnt.

Alumina constitutes a portion of alum, and from which it derives its name. Alumina enters into the composition of an extensive class of bodies, which are very common. Aluminous, or argillaceous mixtures, are generally characterized by the following properties: they adhere strongly to the tongue; become dry, and shrink in the fire, and form a paste with water, which is easily moulded. Most argillaceous stones contain iron, which is the universal colouring principle from brown to the deepest red.

Potter's clay and brick earth contain silex, alumina, and oxide of iron: in common potteries they add sand to render the mass more porous, and by this means to support a greater degree of heat. When vessels are left in this state they easily imbibe water, like the common garden pot. To prevent this absorbency in vessels of general use, they are covered with what is termed a glaze, which is prepared by grinding lead-ore of an inferior quality into a paste with water; the vessels are dipped into this composition previous to their entering the furnace. Vessels are likewise glazed by throwing common salt upon them at a white heat.

Slate forms an extensive class of rocks, which have an argillaceous base: the common roofing slate is one of the varieties of shistus.

Silex. Silicious stones are sufficiently hard to produce sparks, by collision with steel; they are infusible in the fire, and insoluble in all acids except the fluoric; but easily vitrify with an alkali, and form glass. Quartz, or rock chrystal, exhibits silex, more nearly approaching a state of purity than any other natural substance that has been examined.

Chrystals of quartz may be artificially obtained by dissolving silex in fluoric acid, and suffering it to evaporate very slowly.

The common black flint is almost wholly silex, and becomes very white at a high degree of

temperature; it is found in lime-stone and chalk rocks, and is very much employed in the potteries.

There are many different opinions respecting the origin of flint, as it occurs in chalk; some suppose it to be produced by the aqueous infiltration of silicious particles into cavities, which have been formed by air during the deposition and consolidation of the mass. Dr. Hutton supposes that flint in an ignited and liquid state has been forcibly injected upwards between the strata of chalk.

Yttria and zircone are earths of such rare occurrence and are obtained in such small quantities as to render them of little interest, except to analytical chemists.

Bituminous Substances. Vegetable matter in many situations, and particularly if exposed to stagnant moisture, undergoes a gradual change, by which its form is altered, and its constituent principles ultimately destroyed; in this state it is said to be mineralized.

After the vegetable body has undergone this process, which is called the bituminous fermentation, it consists of extractive resin and fibre; and these products, by a continued process, gradually disappear, and the mass becomes proportionally impregnated with bitumen.

When every trace of vegetable organization is lost, the substance becomes of a compact texture, and may properly be called *coal*.

There have been different opinions respecting the formation of coal; it however seems reasonable to conclude that it has been derived from vegetable matter. Bovey coal, obtained near Exeter, and some of the Staffordshire and Welch coal, still retain such traces of vegetable origin as would seem quite sufficient to satisfy the generality of inquirers.

Some of the products arising from the decomposition or distillation of common coal, so much resemble the natural bituminous substances, called naphtha, petroleum, and asphaltum, that if we suppose this vegetable decomposition is constantly passing on in the earth, by means of subterraneous heat, we may not only account for these inflammable bodies, but likewise for the production of different kinds of coal, some of which contain less bitumen than others.

EXTRACTION OF METALS.

NATURE very seldom presents us with uncombined metals; they are found in the bowels of the earth, united with various substances, and it remains for the industry and ingenuity of man

to obtain them from their native beds, and reduce them to a metallic state to supply the various purposes for which they may be required.

Metallic ores are generally found in veins; the value or richness of the ore may be tolerably well estimated by its specific gravity and general appearance; but a more correct judgment may be formed with the assistance of the blowpipe, or the agency of the furnace.

To make an assay of an ore; a small portion of the substance is cleaned and freed as much as possible from foreign matter: the mineral is then pounded and weighed, and exposed in a shallow vessel to a gentle fire, which drives off the sulphur that is generally combined with it. It is afterwards weighed again, and the loss of weight shews the quantity of the mineralizing substances that have been dissipated.

The roasted ore is now mixed with a proper flux and exposed in a crucible to a sufficient degree of heat: the reduced metal which falls to the bottom is then withdrawn, and its weight compared with that of the ore that has been employed.

The object of the flux is to take the oxygen out of its combination with the ore. Different fluxes are employed according to the nature of the oxide; and in the extraction of metals upon a large scale, the treatment varies considerably.

Iron of all other metals, is not only the most

useful, but the most abundant. It pervades the generality of mineral substances, and is the colouring principle that tinges them from the lightest brown to the darkest red. It is stated to enter into the composition of the blood, and to be one of the products of vegetation. Fortunately for mankind, this metal in all its combinations is perfectly wholesome; and if we look to the various purposes of iron, either to supply our wants, or contribute to the elegancies of life, we cannot fail to give it a rank and importance superior to any other metal.

The existence of native or uncombined iron is very doubtful. Professor Pallas, however, asserts that he has found pure iron in a mineral mass of about one thousand six hundred pounds weight, which he discovered in Siberia. From the general composition of this body, it is supposed to be one of those atmospherical productions which have incontestably fallen on different parts of the earth's surface, and which are not only found to possess the same appearance, but discover similar elements when they are subjected to analysis.

These *aerolites*, as they are termed by the French, have been found in places very remote from each other. We have accounts of atmospherical stones which have fallen in Italy, India, England, and America.

One of the aerolites fell on the Wolds, in

Yorkshire, on the 13th of December, 1795, and weighed upwards of fifty-six pounds.

The stone was found to have penetrated through twelve inches of soil and six inches of solid rock in its descent. When it was first extracted it was quite warm, smoked and exhaled a strong smell of sulphur. It was found to consist, like all the rest of the aerolites that have been examined, of metallic iron, pyrites, and nickel, covered with a shell or crust, consisting chiefly of silex, magnesia, and oxide of iron; the specific gravity is about three and a half. Many of these specimens may be seen in the mineralogical room of the British Museum.

The *native magnet* is an oxide of iron in a low degree of oxidation, of a grey colour, and dull metallic lustre.

Iron which remains for a long time in the same position, becomes magnetical, and instruments of iron struck with lightning, frequently obtain a magnetic influence. Even two pieces of iron may be rendered magnetical by rubbing them together. Magnetic iron is very abundant in Norway and Sweden; and it is stated that a large mountain in Persia is entirely composed of this substance.

The *red oxide of iron*, from Ulverston, in Lancashire, is remarkable for the richness of the ore and its beautifully chrystalized appearance. This hæmatite being mineralized by oxygen only,

is easily obtained in its metallic state. Thirty hundred weight of this ore will make a ton of iron.

Argillaceous iron ore is the most common state from which iron is obtained; it is very abundant in Shropshire and Staffordshire, and some other neighbouring counties; and although it does not in general produce more than twenty per cent of iron, it is greatly preferred on account of its ductile quality. This ore is so intimately mixed with argillaceous and silicious earths as to lose all metallic appearance: the specific gravity of the ore is about three and a half; its appearance is that of indurated clay.

In the Forest of Dean, in Gloucestershire, the iron ore has a stalactic appearance, and is found embedded in the cavities of a calcareous rock.

Iron is found in many other states, but the preceding are the most ordinary ores from which it is obtained for the arts; and the following process may be considered as the general means that are employed in reducing them.

The first operation, after the ore has been obtained from the mine, is to roast it, which volatilizes the sulphur and other mineralizing substances; it is then put into the furnace with coke, and as the iron ore generally contains a considerable quantity of argillaceous and silicious matter, a plentiful supply of lime-stone is introduced, which combines with the earthy part, and

forms slag, or an impure glass, that is specifically lighter than the fluid metal, and consequently floats on its surface. When this process is completed, an aperture is made near the bottom of the furnace, and the iron in its crude and fluid state runs out into proper moulds; it is then called pig-iron.

The iron thus obtained is united with a considerable quantity of carbonaceous matter that has been imbibed during its reduction, which renders it too hard and brittle for general purposes. It is therefore broken into pieces and thrown into what is termed the puddling furnace, where it is combined with sufficient heat to soften, without melting it. Whilst the iron is in this situation, it is constantly stirred by long rakes, which are worked by men, from the mouth of the furnace; water is occasionally added, and the carbon combines with the oxygen, which escapes in the character of carbonic acid gas from the mouth of the furnace.

The increasing toughness of the kneaded mass affords the means of estimating the progress of the operation. During one part of the process, an appearance something resembling ebullition, takes place, by the bursting of the newly formed gas through the tenacious fluid that surrounds it.

The last process consists in taking the ductile metal from the puddling furnace, and exposing it to the pressure of an immense hammer, by which

an additional quantity of oxygeneous and carbonaceous matter is pressed out: it is then rolled into bars, or split into smaller pieces for sale. The goodness of iron chiefly depends upon its toughness and ductility.

Carburet of iron is that well known substance, called *black lead;* it has a greasy feel, soils the hands, and leaves traces upon paper; it does not contain any portion of lead, and is composed chiefly of carbon and iron.

Black lead is found in many parts of Europe and America; but that which is obtained from Borrowdale, in Cumberland, is of much finer texture, and of greater brilliancy than any other. From the great value of the Cumberland black lead, the mine is only occasionally worked, so as just to keep up a sufficient supply in the markets.

Iron combines with sulphur, and forms *pyrites* or *sulphuret of iron*, which is a very abundant substance, and has been found at all depths in mining countries. Iron likewise combines with sulphuric acid and forms sulphate of iron or green vitriol.

Copper is frequently obtained in its native state, and is easily distinguished from its different combinations, by its external characters. It is sometimes found distinctly chrystalized, but more frequently ramifying through the substance that contains it.

From the obviously metallic character of

copper ore, this metal engaged the attention of man long before iron or any other.

The savage tribes in the north-western parts of America, although in a very uncivilized state, have applied the copper with which their country abounds, to many domestic purposes. One of the tribes have derived their name from employing copper knives, and are called copper knived Indians.

When native copper is met with in the body of primitive lime-stone and other rocks of that formation, we may fairly presume that it has chrystalized in the situation where it is found; but in some situations it appears to have been the result of a secondary formation, and probably derived from some chemical combination of the metal; or where the copper has been in union with some acid, and the latter body has quitted the metal, from greater affinity.

In the copper mines, in the Island of Anglesea, and other places, it is very customary to throw refuse pieces of iron into the water that has run out of the crevices in the rocks. As this water holds sulphate of copper in solution, the sulphuric acid quits the copper, and combines with the iron; the copper which is thus precipitated in its metallic state, constitutes the purest and best that is obtained.

The red oxide of copper occurs in most of the Cornish mines, and is frequently intermixed with

native copper. This ore is very rich in metal, and is very easily reduced. If charcoal be mixed with the pounded ore, on applying heat, the oxygen readily combines with the carbon, and forms carbonic acid gas: without carbon is used, the oxygen quits the ore with considerable difficulty.

The *grey copper ore* of Cornwall, is likewise very rich; it is mineralized with arsenic, and frequently contains a portion of silver.

The *yellow sulphuret of copper* supplies the greatest portion of the copper of commerce. The sulphur communicates a fine golden colour to the ore, which gives it a very metallic appearance; but it is not near so rich in copper, or so easily reduced, as those ores that have already been mentioned. Sulphuret of copper generally contains a considerable portion of iron, which is separated from the copper by agitating the latter when it is in a fluid state; this presents fresh surfaces to the atmosphere, and suffers the oxygen to combine with the iron, and take it out of its union with the copper. The oxide of iron which is thus formed, is occasionally removed from the surface, until the copper has been sufficiently purified.

On account of the cheapness of fuel in Wales, great quantities of copper are sent from Cornwall and Anglesea, to Swansea and other parts, to be reduced into a metallic state.

Roasting constitutes the first part of the process,

which separates the sulphur from the copper ore. This is generally effected in large chambers, by passing flame over the surface of the ore after it has been broken down into fragments. The sulphur has such great affinity for the metal, that this process has frequently to be repeated before it is sufficiently dissipated.

The roasted ore is then melted in furnaces, from which it runs into basons, or into vessels filled with water, to granulate or divide it, that it may be the more easily acted upon in the subsequent processes.

This is the first metallic state in which it is obtained; the metal is very brittle, and possesses a blackish brown colour, containing a less portion of sulphur than the native ore; but in other respects equally unfit for commercial purposes.

The copper is again fused and run out; and this process is sometimes continued four or five times before it is obtained in a marketable state; when it is sufficiently purified, it is formed into blocks and bars for sale.

Copper occasionally combines with carbonic acid, in its native bed, and forms *carbonate of copper*, or *malachite*; this is very easily reduced, as it only requires to be fused with charcoal; but a sufficient quantity of metal is never found in this state, to render it a sufficient object for commercial speculation.

Lead, in a native state, is of doubtful existence;

there are some specimens that are said to be of this description; but from the great facility with which this metal is reduced, and the great length of time that lead mines have been worked, it is very probable that they are nothing more than the remains of some old mine work, incrusted with other substances, and so far changed in appearance as to give them the stamp of natural productions.

Sulphuret of lead, or *galena*, is met with in all parts of Europe, in great abundance, and no where in greater quantity than in England.

The lustre and colour of galena, before it becomes tarnished, exactly resembles lead in its metallic state. The greatest part of the lead of commerce is obtained from this ore. It is first roasted, to drive off the sulphur, then mixed with charcoal, and put into a furnace. After the operation of roasting, the lead is in an oxidized state; the charcoal decomposes the metallic oxide, and combines with the oxygen, which flies off in a gasseous state, and leaves the metal at the bottom of the furnace, from which it is run out into moulds for sale.

Almost every variety of the sulphuret of lead contains a greater or less proportion of silver. When the lead is in a fluid state, the silver is separated, by throwing a current of air upon its surface, which converts it into a yellow scaly oxide, called litharge. This is removed as soon

as it is formed, until the whole of the lead is withdrawn, leaving the unoxidized silver at the bottom of the crucible. The quantity of silver contained in lead ore is very variable; sometimes not one part in a hundred, and very seldom exceeding six or seven. In England the quantity is so small that it is rarely extracted.

The *carbonate of lead* occurs more commonly than any other combination of lead, except galena; but it is very rarely found in sufficient quantity to be worked on a large scale; it is very easily reduced, and generally accompanies galena and ores of zinc. Lead, in a natural state, combines with phosphoric, arsenic, molybdic, and chromic acids, forming beautiful chrystalized bodies.

TIN. The existence of this metal, in a native state, is nearly as questionable as native lead. A mineral substance is sometimes met with in Cornwall, which is called native tin; and a similar body has been met with in France; but Haüy thinks they are artificial products.

The *oxide of tin* is the ordinary state of the metal: it is sufficiently hard to strike fire with steel, and varies from a jet black to a light brown, or even white. Tin ore is more plentifully found in Cornwall than in any other part of the world, and the mines from which it is obtained are generally about two hundred fathoms deep.

The specific gravity of this ore is very nearly

equal to that of the metal itself; whereas the specific gravities of other ores are generally much less than those of their metals.

Stream tin is an oxide, and is generally found in low situations, between the sides of hills: it appears like sand of a dark colour, and is sometimes found in the form of small pebbles; but they very rarely exceed the size of an apple.

The space from the surface of the stream works to the place where the tin ore is generally found, is composed of sand, loose earth, or clay, deposited without any regularity, and often contains moss, branches of trees, and even animal bones. From the general appearance we might be led to conclude, that at some former period, a violent current of water had detached masses of tin ore from their native situation, and that the abraided parts had been deposited in their present bed with earthy and other substances which had likewise been swept away by the current.

The reduction of tin ore is effected by merely fusing it with charcoal; the carbon of which combines with the oxygen of the ore, and leaves the metal in its pure state. The Cornish ores are, however, generally mixed with arsenical pyrites, which makes it necessary to roast them, to dissipate the arsenic previous to their reduction.

ZINC. The ores of zinc are generally oxides or sulphurets.

The oxide of zinc is called lapis calaminaris,

or calamine: it is very plentifully found in Mendip Hills, in Somersetshire, and likewise near Matlock, in Derbyshire. The general appearance is corroded or carious; but it occurs chrystalized, and is sometimes found incrusting galena and carbonate of lime.

Zinc is more frequently mineralized by sulphur, in which state it is called *blende*, or *sulphuret of zinc*. The chrystal is generally of a very dark brown, approaching to black: it is one of the commonest of the metallic ores, and easily divisible into laminæ. The sulphuret of zinc frequently forms incrustations on the surface of other metals and some earths; it generally accompanies galena; its matrix is usually quartz or carbonate of lime; and, like all other sulphurets, it emits a disagreeable smell by friction.

To reduce the sulphuret of zinc, it is first roasted, and then fluxed with charcoal. Oxides of zinc, like the other metallic oxides, only require charcoal for their reduction.

Zinc is employed with other metals to form various compounds. Melted with copper, it constitutes brass; when tin is added to the zinc and copper, it forms bronze or bell-metal.

There are many other ores besides those that have been mentioned; but they are of very inferior importance in the arts, except gold and silver, the former of which is obtained in a pure metallic state: we will, therefore, close this part of the

subject with the preceding account of our own native metals, all of which, saving zinc, have been worked from the earliest periods of our history, and have been peculiarly instrumental in those arts which have brought this commercial country into the high and dignified position which it now holds in the eyes of the world.

MECHANICAL PHILOSOPHY.

IT has been stated at the commencement of the present subject, that all the *operations* of inorganic matter are reducible into two parts; "*Chemical* and *Mechanical.*" The *chemical* part has been traced, in a general way, through all its various windings; from the primary influence of Light, Heat, and Electricity, to the general principles of the subject, and the application of chemistry to many of the arts; and it has concluded with an outline of geological science. We now advance to the mechanical operations of nature, where we do not stop to examine the composition of bodies, or the peculiar properties which their elements possess; but only look at the quantity of matter aggregated and wholly abstracted from any other influence than that of motion.

Matter; and *motion* either actually existing, or suppressed by the opposition of forces, constitute the whole subject of *mechanics.*

Bodies derive their weight from the influence of a principle impressed upon matter, by the *fiat* of the Creator, which is called ATTRACTION. We daily witness its effects, and Newton has decided upon its laws; but its principle still rests in the bosom of nature; and like the elements of light, heat, and electricity, is probably too subtile for the faculty of man to comprehend in the present state of his existence.

Every body possesses an influence of attraction, according to its quantity of matter: on this account the influence of the earth's attraction governs and gives weight or gravity to smaller bodies, on or near its surface; and the effects of attraction diminish as the squares of the distance from the centre of the body. That is, if a body be supposed to be placed at any given distance from the surface of the earth, it is acted upon by the influence of its attraction: this gives it a certain degree of weight or gravity, according to the quantity of matter contained; but if the body be supposed to be removed to twice this distance from the earth's centre, the influence of attraction, consequently its weight, is diminished four fold: at three times the distance, the diminution is nine times as great, and so on.

The same laws which are applied to bodies on or near the earth's surface, equally extend to our system, and govern all the planetary bodies in their revolutions.

Solid bodies, formed by the influence of attraction, are governed by the three following laws of MOTION.

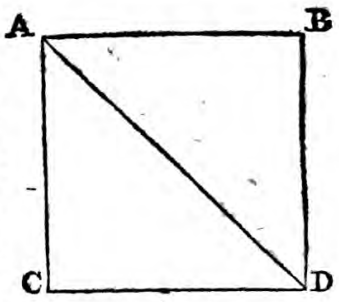
First. Every body continues in a state of rest, or moves uniformly in a right line, unless it be compelled to change that direction, by the action of some external force.

Although this law does not visibly operate on the surface of the earth, our reason readily assents to the position. If a body be supposed to be in motion, in a region devoid of all resistance, we cannot imagine how that body can possibly lose any part of its velocity, or be deflected from its course, without some external power operating upon it.

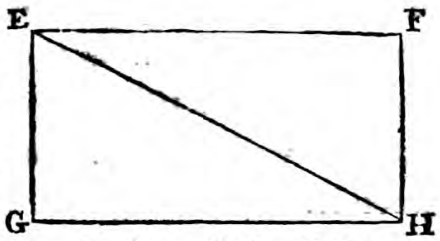
Second. The change of motion is always proportional to the moving force by which it is produced, and it is made in the line of direction in which that force is impressed.

By the first law, motion cannot be generated in a body without some external impulse; and as the motion thus generated is directed in a right line, with a velocity equal to the degree of impulse, the course of a body in motion can only be altered by a fresh impulse, which is compounded of its own velocity and the impelling force; so that the body will be either accelerated or retarded in a right line course, in proportion to the compound force of the two impressions.

In the figure A B C D, if a body be put in motion by an impelling force, in the direction A B, and at the same instant it be acted upon in an equal degree by another impulse, in the line A C, the body will be projected in a direction compounded of the two forces, which is represented by the line A D.



If the impulse, E F, be greater than E G, draw the sides parallel to each other, and the diagonal, E H, will give the direction and relative velocity of the body.



Third. Action and re-action are always equal and contrary; or the action of two bodies on each other, is always equal, but in contrary directions. For if a stone be pressed by the hand, the re-action, or compressive force of the stone on the hand, is equal to the pressure upon the stone. Or, when a horse draws a load, the power of the horse is diminished, or is drawn back with a force equal to that which puts the load in motion: for if the weight of the load be increased, until it is equal to the strength of the horse, it will remain at rest, although the whole force of the animal be in action.

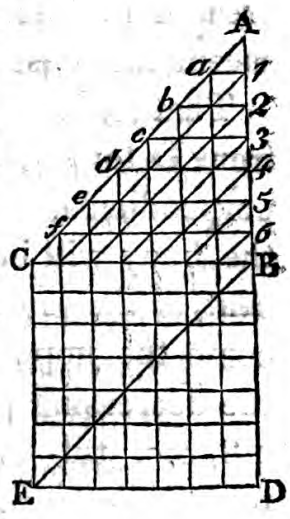
GRAVITATION is that force with which bodies

are put in motion, and fall in a line directed towards the centre of the earth.

The power of gravity is the same in all bodies; therefore, taking away the resistance of the atmosphere, the descent of bodies from the same height, is performed in the same time, whether they be great or small, light or heavy.

Falling bodies descend with an increasing velocity. This accelerated motion is produced by the constant power of gravity; which, by adding a fresh impulse at every instant, gives an additional velocity and an increasing motion.

The space through which a body falls in the latitude of London, is $16\frac{1}{12}$ feet in the first-second of time; four times this distance in two-seconds; nine times in three-seconds, and so on: increasing in velocity as the squares of the distance through which the body descends.



Let A B represent equal parts of time through which a body is accelerated in falling; then the velocity acquired in passing through each space, by the continual impulse of gravity, is relatively as the lengths of the parallels, a 1, b 2, c 3, &c. throughout the whole figure: that is, the velocity increases as the lines increase in length, and the quantity of the velocity is equal to the square of the time. For if 5 e, represent the velocity

acquired in falling through the space, A 5, the sum of the velocities, or all the similar triangles taken together, that are contained in A 5 e, will amount to twenty-five; which is equal to the square of the time, A 5, and so on of any other point of time.

The spaces described by an uniform motion with the last acquired velocity, during a time equal to that of the acceleration from the beginning, will be double the space described by the accelerated motion. For if B D be equal in time to A B; and B C, and its parallels express the equable time of motion; the parallels likewise express the velocities, as in the preceding case; but they are double the spaces of the accelerated motion.

Bodies projected upwards have their velocities diminished in the same ratio that they are increased in their descent; so that the times of ascent and descent are equal.

That is, if a body be projected from D towards B, and B C be the perpendicular line of gravitation, the body will be retarded in its ascent, or the gravity, B C, will overcome the impetus in proportion to the decreasing parallels, a 10, b 9, c 8, &c. till the whole projected force is destroyed.

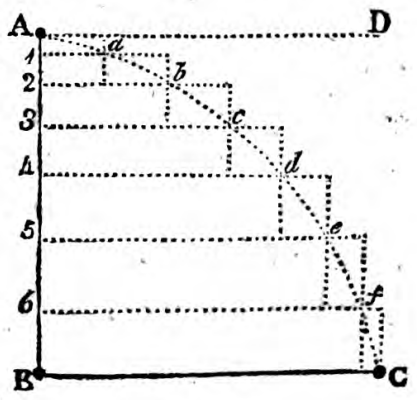
When the body returns, it will fall from B towards C with an

accelerating force, increasing as the parallels increase, till it reaches the surface: so that according to this law the ascending and descending times are equal.

The law of acceleration in *bodies* descending perpendicularly, holds equally in point of time with those that are *projected.*

For if a stone be dropped from the top of a tower, and another at the same time be thrown horizontally, the two bodies would reach the ground at the same instant, supposing them to meet with no resistance from the atmosphere. Even a cannon ball fired horizontally, from an elevated situation, would reach the earth in the same time that another ball would fall upon it in a perpendicular direction. This necessarily arises out of the second law of motion; for the ball being acted upon by the projectile force derived from the gunpowder, and the influence of gravity, it takes a direction compounded of these two forces, and describes its course in the same time that the body would fall to the ground by the influence of gravity alone.

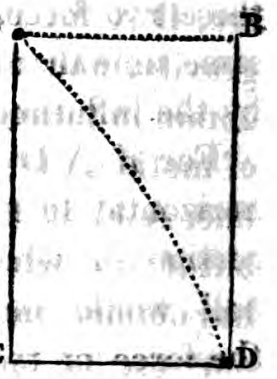
For if A D be the horizontal line of direction in which the ball would move by the force of the gunpowder, and A B the perpendicular line of gravitation, then the



ball will move in the line A C, which is compounded of them both, and it will pass through the line A a, in the same time that its gravity alone would carry it from A to A 1, and the time A 2 is equal to the time A b, A 3 to A c, and so on through the whole; making the time of A C to A B.

When the forces are uniform, the body acted upon moves in a right lined direction; but in all cases of projectiles the forces are not uniform; the influence of gravity is a continually accelerating force, represented by A 1, A 2, A 3, &c. and the projecting force A D, is uniform: in this case the projected body passes through a curve, or describes a parabolic arc in the line of its projection.

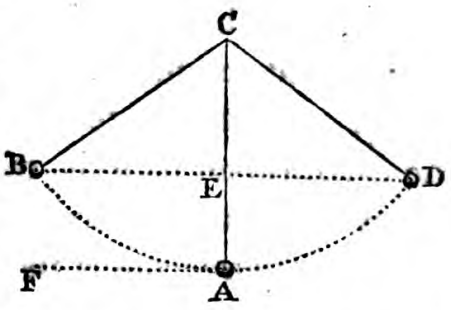
If a stone be dropped from the top-mast of a ship, whatever may be the velocity with which the vessel moves, the stone will still fall exactly at the bottom of the mast.



Let A C be the ship's mast and its position when the stone is dropped from it; C D the distance sailed during the time of its descent; and B D the situation of the mast when the stone strikes the deck. Now the force or projecting velocity of the vessel, C D = A B, carries the stone towards B, and the force of gravity acts from A towards C;

but the compound force carries the stone to D, in the direction A D, and in the same time that it would fall from A to C, if the vessel were at rest. The velocity of the stone and vessel being equal, it apparently drops perpendicularly down the side of the mast, as it describes the curve of projection.

A pendulum is a heavy body, suspended by a small cord or piece of wire, which moves about a point as its centre. When the weight is put in motion, it will descend through one half of an arc by its own gravity, and ascend the other half by the velocity which it has acquired in its descent.



If A be a weight suspended by a line or wire, from the centre C, when it is let fall from D, it will descend through the arc, D A, by its own gravity, and acquire such velocity as it would obtain in falling from E to A. By the first law of motion, the weight would fly off in the straight line, A F, if it were not retained by the string; but it is conducted to B by the force which it has obtained at A, and the whole arc, D B, forms one oscillation. At B, which is in the same horizontal line with the opposite point, D, it loses

its motion, and then returns back by the force of its gravity.

Thus, the pendulum would continue moving for ever, if it were not perpetually retarded by the friction of the cord or wire at the point of suspension, and the resisting medium of the air through which it vibrates; but these gradually retard its motion, so that each oscillation becomes something less than the preceding, till at length the ball rests in the line of suspension.

The time of the vibration of pendulums, is as the square root of their lengths; that is, if one pendulum be four times longer than another, it will vibrate half as fast; if it be nine times longer, one-third as fast; if sixteen times, one-fourth as fast, and so on.

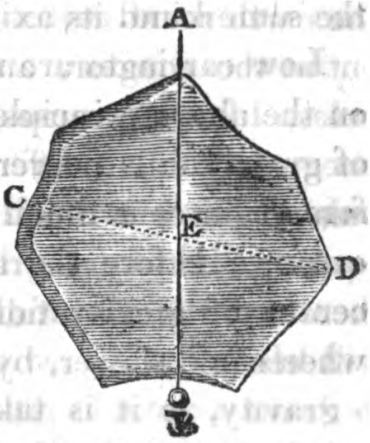
The centrifugal force, or rotatory motion of the earth round its axis, which causes it to swell out at the equator, and flattens it towards the poles, likewise causes pendulums to vibrate in unequal times, in different latitudes. For the repulsive or centrifugal force is greatest at the equator, and lessens gradually towards the poles; therefore the vibration of the same pendulum will become slower, by the increasing resistance to gravity, as it is taken towards the equator, and faster, by the decreasing power, as it approaches the poles of the earth.

A pendulum 39.2 inches in length, vibrates

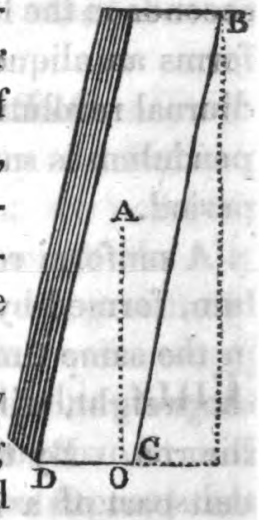
seconds in the latitude of London, and as a second forms an aliquot part of the time occupied in a diurnal revolution of the earth, the utility of the pendulum is sufficiently obvious in marking this period.

A uniform rod, one-third longer than a pendulum, formed by a wire and weight, will vibrate in the same time, and the centre of oscillation in the weight, will be the centre of percussion in the rod. By the centre of percussion is meant, that part of a rod or stick, which produces the greatest impression in striking a blow.

The centre of gravity of a body, is that point about which all the parts exactly balance each other; therefore, if this point be supported, the body will be at rest, whatever may be its form.



The centre of gravity of any superfice may be found thus: let the body be freely suspended by a string, and apply a plumb line to A, the point of suspension: this will pass over the centre of gravity somewhere in the line, A B; now mark this line, and then hold the plumb line from C, another point of suspension, and the point E, where the lines cross each other, is the centre of gravity.



If a body be placed on a horizontal plane, and a perpendicular line, A O, from A, the centre of gravity fall within its base D C, it will stand: if the line falls beyond the base, the centre of gravity, A, loses its support, and the body descends.

Whilst the centre of gravity falls within the base, inclining walls support themselves, and old buildings remain with their tops overhanging for many years.

The tower of Pisa, in Italy, is a remarkable instance of this kind; for the top of the tower overhangs the base sixteen feet. The tower of Caerphilly, in Glamorganshire, is another of the same kind.

Low carriages are much safer than high ones, on the above principle; inasmuch as the centre of gravity falls nearer to the ground, and therefore requires a much greater inclination of the carriage before the line of direction from the centre of gravity falls beyond the rim of the wheels.

MECHANIC POWER.

THIS aids the exertions of man, and enables him to overcome resistances that his own physical strength could never effect.

In this, as well as every other civilized country, much of its wealth and greatness depends upon the extent of its arts and manufactories; and these, upon the proper application of the chemical and mechanical laws of nature.

Man, in an isolated state, would scarcely be able to supply his own immediate wants by the whole of his exertions; but united in society, and enjoying the advantages derived from the progress of science, he not only administers to his own necessities, but likewise relieves the wants of others; for his arts and manufactories are carried through the trackless ocean to the most distant parts of the earth.

When the physical strength of man is insufficient for the purposes required, he has recourse to those mechanic principles which constitute some of the general laws of nature, and constructs a simple or a compound machine; this he makes the

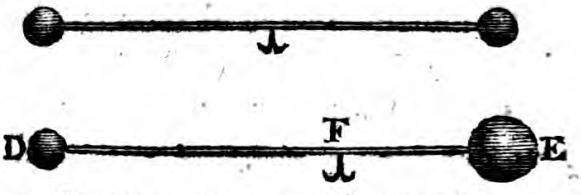
intermediate means between his own power and the object to be obtained.

But when a man's strength with this auxiliary machine, is still insufficient for his mechanical purposes, he substitutes the power of weights, springs, horses, wind, water, or steam, according to the degree of resistance to be overcome, and from some of these he can obtain such an unlimited resource, that he has only to look to the strength or stability of the intermediate apparatus between the power and the resistance to obtain any degree of force.

All *mechanic power* is derived from the difference of velocity between the acting and resisting forces.

In every engine, simple or compound, the thing to be effected constitutes the resisting force; and the power to effect it, the acting force.

If a handspike be employed by a man to remove a stone from its bed, the acting force is applied by the hand at one end, and the resisting force is the stone at the other. When the handspike is put in motion, the difference of velocity between its two ends expresses the power obtained by the instrument.



If two bodies of equal weight be fastened to the extremities of an uniform rod, the centre of gravity or

equilibrium will be equidistant from them; or if the rod be put in motion on this centre, the two extremities, or the acting and resisting ends, possessing similar velocities, there is no mechanical power obtained. But if the bodies be of unequal weight, the point of gravitation in the rod will be according to these weights. That is, if E be to D, as three to one, then F E will be to D F, as one to three; or the length of the arms will be inversely proportional to the weights; and the velocity of D to E, will be as three to one. Now, supposing D to represent the power of a man, and E the resistance opposed to him, his power is equal to the resistance, and his strength is mechanically increased threefold by the use of the lever.

The centre of gravity, or point of equilibrium obtains, when the sums of the velocity of each end, multiplied into the weight of the bodies, are equal; or D F × D=E F × E.

If two balls containing unequal quantities of matter be projected separately from a spring, the height to which they ascend is inversely as the quantity of matter: that is, if the smaller body contain three times less matter than the larger, it is projected to three times the height; or the sum of matter and motion in each is equal.

If a cannon ball of three pounds weight, be projected with a velocity expressed by ten, the force or momentum of the ball is thirty; but if

a ball of ten pounds weight be expelled with a velocity of three, the sum of matter and motion is likewise thirty; and the effects of these two balls in overcoming any obstacle against which they might be projected, is still the same in both cases.

These general laws of nature, or effects of matter and motion, not only illustrate the mechanic advantage of different instruments and machines, but the same principles equally apply to the *revolution of the planetary bodies* in our system, and account for that divine order and harmony which prevade the whole.

If we imagine the earth and moon connected by means of a uniform rod, the centre of gravity between them is as much nearer to the earth, as the quantity of matter contained in it exceeds that of the moon.

This is the common point about which these bodies actually revolve, and which describes what is generally termed the earth's orbit. Its distance from the centre of the earth is six thousand miles, and two hundred and thirty-four thousand miles from the centre of the moon.

If the velocity of the earth round this centre of gravity, be multiplied into the quantity of matter which it contains, the sum will be equal to the quantity of matter contained in the moon, multiplied into its velocity.

Now if we suppose all the planetary bodies,

both primary and secondary, to be placed on a uniform rod, with the sun fixed at one end of it, there would be a point somewhere between the sun and the planets that would balance the whole; this is the centre of gravity of our system, and about which the sun and planets revolve, however they may be dispersed in their respective orbits.

The centre of the system is about eight hundred thousand miles from the centre of the sun; and the quantity of matter contained in the sun is about six hundred times greater than that which is contained in the whole of the planets.

Dr. Herschel states, that the centre of our system is not a stationary point in the heavens, but that it has a continued motion directed towards the constellation Hercules; and he is led to conclude, that the whole revolves round, and obeys some other centre.

How beautiful are these laws of nature!—what admiration they excite in the contemplative mind!—how much we are charmed with the unity and design which is manifested by the first cause, when we observe that the same laws which have the most insignificant operation upon the earth's surface, are extended to the heavens, and govern the revolutions of all the bodies contained in the universe.

Mechanical Instruments and *Machines.* All machines are composed of simple instruments;

therefore, to estimate the power of a compound machine, we must reduce the parts into their simple state; then estimate the power of each, and multiply these respective powers together, to obtain the sum of the whole; abating at least one-third part of the estimated force for friction amongst the different parts which are in contact.

Under this consideration, the first object in estimating the quantity of mechanic force, is to consider the power and properties of a certain number of instruments, which include all the simple *mechanic powers:* these are the lever, wheel and axle, pulley, inclined-plane, wedge and screw.

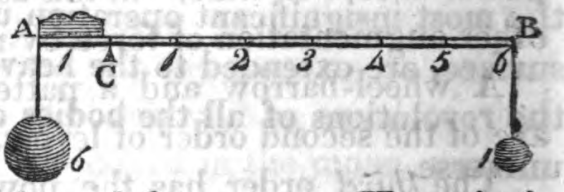
The *lever* has three different modes of operation.

The first of these is, when the weight to be moved is on one side of the fulcrum or prop, and the power which is communicated lies on the other.

The second description is, when the weight is between the prop and the power.

The third is, when the power is applied between the prop and the weight.

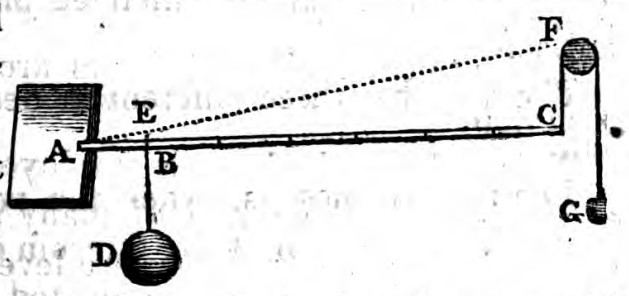
The lever A B, is of the *first* kind, and has the prop C, between the weight and the power. Here six is taken as the resistance, and one the power; and



the resistance is as much nearer to the prop C, as the power is less than the resistance; so that the power of the lever is as the difference of the arms, or the difference of the velocities of the bodies at each extremity.

Scale-beams, fire-poker, scissors, snuffers, pincers, and many other mechanical instruments, are of this order of the lever.

The *second* kind of lever has the resistance and power on the same side of the prop; but the advantage gained is still in proportion to the difference between the longer and shorter division.

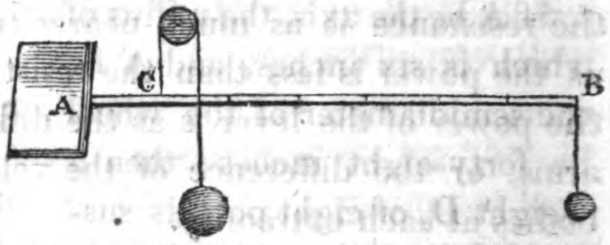


If one end of the lever A B C, be supported at A, and A C be seven times longer than A B, seven pounds suspended at D will be balanced by one pound at G; but to raise the weight a foot or an inch from B to E, the end C, must pass through seven times that space, or from C to F; so that, "what is gained in power is lost in time," in this as well as in every other augmentation of force by mechanic power.

A wheel-barrow and a patten-maker's knife are of the second order of levers.

The *third* order has the power between the prop and the weight, and may be considered as the reverse of the second.

Let the lever A B, be divided into seven equal parts,



and A C be equal to one of these parts: if a ball of one pound be suspended from the end B, it will require a force of seven pounds pulling upwards at C to balance it.

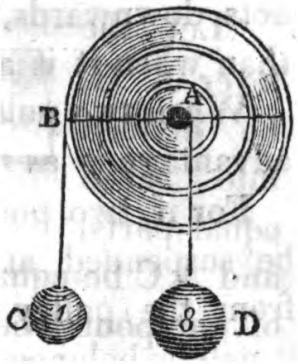
As there is a mechanical disadvantage in employing this order of the lever, it is only used for convenience, when there is a redundancy of power.

Sugar-tongs and wool-shears are of this description.

This order of the lever is employed with great convenience in the action of many parts of the animal body; for the bones are levers, the joints fulcra, and the muscles the power that gives motion to the whole.

The *wheel* and *axle* may be considered as a perpetual lever, having the prop in the centre of the axis and wheel. The acting, or longer part of the lever, is the radius or half the diameter of the wheel; and the shorter, or resisting part, is the radius of the axis: the power or weight, falls perpendicularly from the circumference of that part of the wheel which is in a horizontal line with the axis.

If A be the axis, the radius of which is six inches, and A B, the semidiameter of the wheel be forty-eight inches; then a weight D, of eight pounds suspended from A, will be balanced by one pound at C, hanging from B.

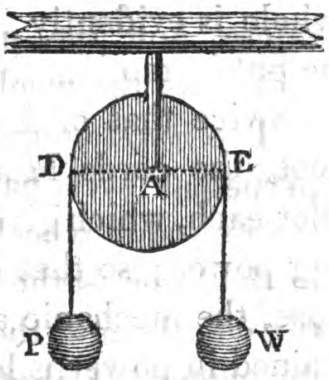


This power has many useful modes of application; it operates in the capstan, crane, and other machines, where a roller and handle are employed.

The *pulley* is a mechanical instrument, formed by a small wheel, with a groove in its circumference, which is placed in a frame, and turns upon its axis.

A singly pulley does not give any additional power.

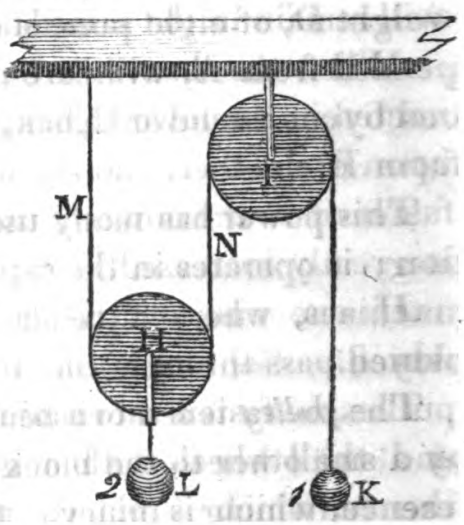
If the pulley A, support two equal weights, P and W, they will counterpoise each other in the same manner as if the cord were cut into two parts, and each tied to the end of a balanced beam, which is represented by DAE.



The principal advantage that arises from a single pulley, is in the mode by which the power is applied; for in raising a loaded basket, or bucket, by a line passing over a pulley, the force

acts downwards, which is much less laborious than when it is applied in an opposite direction.

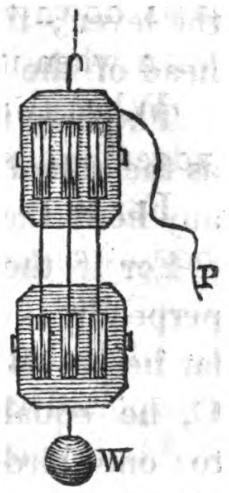
When two pullies are employed, the mechanic advantage is as two to one.



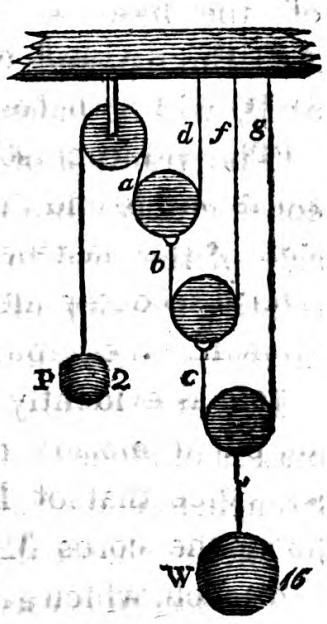
For if two pounds be suspended at L, from the pulley H, it will be balanced by one pound hanging at K. It is evident that the weight L, is equally divided between the two cords M N, and each supports one pound: the cord M, is fastened to the beam, and N passes over a second pulley: if one pound be suspended from K, it equipoises the power at N, and the whole is evidently in equilibrio. If the bodies be put in motion, the velocity of K, will be equal to twice that of L; for if the pulley H, rises a foot, the cords M and N, must be shortened a foot each, which gives two feet to K, the descending power; so that in this, as well as every other case, the mechanic axiom applies, that "what is gained in power is lost in time."

If a fixed and a moving block have each of them three sheaves, and a weight W, be suspended from the lower block, it will be counterpoised by a sixth part of this weight, hanging

from P. Inasmuch as the whole weight is equally divided amongst the six cords, if one of these cords be kept in equilibrio, all the others will remain in the same state.



When the sheaves are not connected in the lower block, but act upon each other, and the weight is fastened to the lowest, the power is greatly increased.



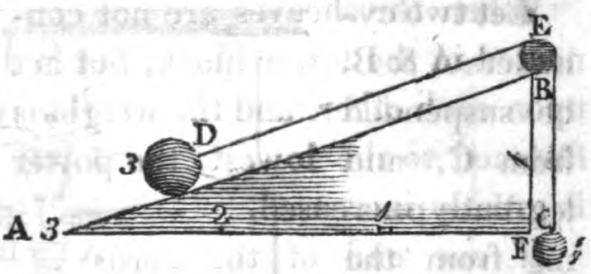
If one end of the cords which pass through the four pullies, be fastened to a beam, and the other to the block of the adjoining pulley, the weight will be divided in such a manner amongst the different pullies, that sixteen pounds at W will be balanced by two pounds at P. For if c g suspend sixteen, the eight pounds suspended by c, is divided between b and f; then b supports four pounds, which is again divided between a and d; and the two pounds at a, is counterpoised by two pounds the power P. The eight, four, and two pounds at g, f, and d, are supported by the beam.

The six mechanic powers are reducible to two principles; the three preceding, contain that of

the lever; the remaining three come under the head of the inclined plane.

The base is to the height of the *inclined plane*, as the actual gravity is to the relative gravity of any body that rests upon it.

For if the perpendicular height B C, be equal to one-third of the base A C, three pounds resting upon the inclined plane, at D, will be balanced by one pound at F.



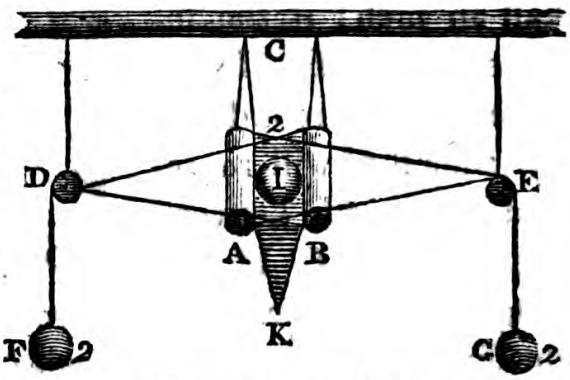
The traction of a loaded carriage up a hill, is considerably diminished by crossing from one side of the road to the other; inasmuch as the relative gravity of the carriage is diminished by increasing the length of the inclined plane.

It seems highly probable that those immense masses of stone that are piled upon each other, at Stonehenge, on Salisbury Plain, have been raised by the mechanical means of the inclined plane.

The *wedge* is used for raising great weights, or separating blocks of wood or stone, by driving it into the mass.

The doctrine of the wedge has been differently considered by different authors; but as there are so many natural obstructions to overcome in its operation, such as elasticity, tenacity and friction, the practical effect cannot be brought to

serve as a proof of the theory. It is, however, generally considered, that the power which acts against the back, is to the force acting perpendicularly against each side, as the breadth of the back of the wedge is to the length of its side.

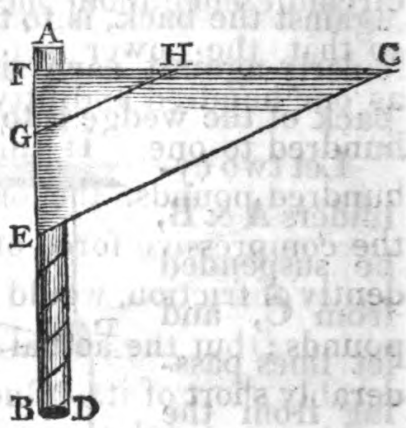


Let two cylinders A & B, be suspended from C, and let lines passing from the axis of each cylinder over the pullies D E, suspend weights of two pounds each, at F and G. Now, supposing the cylinders to be pulled against the wedge with a force of two pounds each, and the length of the wedge B K, to be equal to twice its thickness A B; the pressure of two pounds upon the top of the wedge at I, is equivalent to four pounds the resistance from the sides of the cylinders.

An experiment of this description is by no means conclusive with respect to the operative power of wedges; for we are well aware that a hammer of fourteen pounds weight, with a smart blow, would drive a wedge further into a piece of wood, than a ton, acting with a dead pressure upon its head.

Screw. As the power of the inclined plane is as its base to its height; so the power of the

screw is as the circumference of the cylinder to the distance of the spirals.



Suppose the circumference B D=F H, be five inches, and F G, half an inch; if the inclined plane, F G H, be rolled once round the cylinder F G will represent the width between the spirals; G H the length of the spiral in one revolution, and F H, the circumference of the cylinder; and the power of the screw will be as H F to F G; that is, as the base of the inclined plane to its perpendicular height.

If E F and C F be five times G F and F H the paper will roll five times round the cylinder; and the edge of the inclined plane E C, will form a spiral of five revolutions at half an inch apart.

To estimate the force of the screw. If the threads or spirals on the cylinder A B, be made a quarter of an inch asunder, and the nut D, be turned by a handle or lever C D, two feet from the centre of the screw; as the power of the screw is relatively as the circumference to the dis-

tance of the threads, the diameter of the power will be twice C D, or forty-eight inches, and its circumference about one hundred and fifty inches: so that the power is to the force or pressure, as one hundred and fifty, to one-fourth, or as six hundred to one. If this be multiplied by one hundred pounds, the ordinary power of a man, the compressive force of such a screw, independently of friction, would amount to sixty thousand pounds; but the actual power would fall considerably short of it. One-third, and in some cases nearly one-half of the calculated force, must be deducted for the friction or attrition arising from the action of the interior and exterior spirals upon each other.

Friction or *attrition.* Levers, axles, pullies, wedges, and screws, in their simple or compound state, are considerably retarded by the rubbing of the moving parts upon each other.

Friction is considered as a uniformly retarding power, in hard bodies, and not subject to alter by different degrees of velocity: it increases in less ratio than the quantity of matter or weight of the body, and the smallest surface or the fewest parts in contact, has the least friction, the weight being the same.

The force or power of friction varies accordingly as the surfaces in contact are hard or soft, rough or smooth; even the hardest bodies, with

the highest polish, are not free from inequalities on their surface, and which retard the motion.

The friction arising from the action of fixed surfaces upon each other, is much greater than when they yield or give way.

The friction or retarding force produced by a sledge, on the road, is much greater than that which obtains by the revolution of a wheel. Wheels are locked in going down a hill to increase the friction of the carriage, that the descending velocity may not overpower the horses.

The friction arising from the different parts of machinery in contact, is greatly diminished by adding rollers, which yield to the inequalities of the surfaces, and revolve round their own axis. Some few years ago the following ingenious contrivance was introduced, but the expence of the apparatus has been thought greater than the additional advantages which are derived from it.

C C represents the nave, A the section of the axle of a carriage, and B B, small cylindrical rollers, which are placed in a case that is contained in the nave. The axle of the carriage rests upon these rollers, so that when the wheel is in motion, they not only turn round their own axis, but they are carried round the axle of the carriage in the

frame that holds them together. This compound diminution of friction, may certainly be employed in some cases, with very great advantage.

Cylindrical and spherical rollers are conveniently used in turning heavy bodies, and moving blocks of wood from one situation to another.

The base of the grand equestrian statue of Peter the Great, is formed of an immense block of granite, which was brought from a place some miles distant from Petersburgh, by rolling it on the road, on iron balls, laid on thick planks.

AIR.

WEIGHT and *elasticity* constitute the *mechanical* properties of air, whatever may be its composition.

The *atmosphere*, or *air* we breathe, is a thin, transparent and elastic fluid that presses on the earth by the influence of gravity, and surrounds it to an indeterminable height.

The atmosphere distinctly considered, or rather that part of it by which we exist, is equally disseminated in invariable quantities throughout the whole surface of the earth; but independently of this air, the atmosphere is a chaotic mass, compounded of every body that is capable of being volatilized by fire, or dispersed by putrefaction, exhalation, fermentation, evaporation, or any other principle that changes the fixity of animal, vegetable, or mineral bodies.

The *weight* or *pressure* of the atmosphere is produced by the influence of the earth's attraction upon its corpuscles. This effect being the most powerful nearest to its surface, causes the elastic fluid that surrounds the earth to diminish

in density from the surface to an unlimited extent.

The pressure of the atmosphere has likewise an equal influence upon the animal body; and as fluids press equally in every direction, we are constantly sustaining a great pressure, but are perfectly insensible of it from its general operation. If this pressure be partially removed we sustain considerable pain and inconvenience, and if wholly taken away from the body of a small animal, it instantly loses its existence.

If the hand be placed upon a small glass, open at each end, on exhausting the air, the muscles are considerably distended in the uncompressed part, which produces a painful sensation, and we have considerable difficulty in raising up the hand from the surface of the glass.

As heat rarefies and displaces air, the same effects may be produced by putting a piece of burning paper in a wine glass and placing the hand evenly upon it.

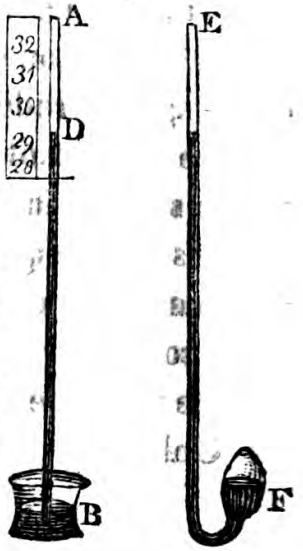
The elevation of the muscle for the operation, cupping, is produced as above.

The weight of air has a very sensible effect on a fine scale beam: a pint of atmospherical air weighs about eight grains, and its specific gravity compared with water, is about eight hundred and sixty to one.

The pressure of the atmosphere was discovered by Galileo.

It has been known many ages, that water would rise in an exhausted tube, or in the cylinder of a pump, to the height of about thirty-four feet, but no higher. Galileo imagined that this limited ascent might be the counterbalancing power to an equal column of the atmosphere; and his disciple, Torricelli, proved that quicksilver, or any other fluid, differing in specific gravity from water, would rise to a proportionate height. He found that if a glass tube were filled with mercury, which is about fourteen times heavier than water, and the open end were immersed in a bason containing a small portion of this fluid, the mercury would stand at the height of about two feet and half, or at one-fourteenth part of the height of a column of water.

This constitutes the principle of the barometer, whatever may be its construction; an instrument that has been found of considerable importance in many departments of natural enquiry.



If A B or E F be a small glass tube, about thirty-four inches long, closed at one end and filled with mercury; on inverting the tube, the mercury will sink to a point somewhere between twenty-eight and thirty-one inches from the surface in the bason B or F, leaving a vacuum in the upper part of the tube. This void

opposes no resistance to the rising and falling of the upper surface of the mercury; therefore leaves the free action of the atmosphere on the lower part; and the column can fluctuate, or rise and fall in the tube, as the atmospheric pressure varies on the surface of the mercury in the cup.

The atmospherical variation being contained between twenty-eight and thirty-one inches, twenty-nine inches and half may be taken as the height and weight of a column of mercury which is equal to the pressure of a column of the atmosphere of the same base.

A cubic inch of mercury weighs about eight ounces; therefore, a pillar of mercury an inch square, and twenty-nine inches and half high, weighs nearly fifteen pounds, which is equal to the pressure of the atmosphere upon every square inch of the earth's surface.

Fifteen multiplied by one hundred and forty-four, gives two thousand one hundred and sixty pounds for the pressure on a square foot. The body of a middle sized person contains a surface of about ten square feet; so that the atmospherical pressure upon the human body, is not less than twenty thousand pounds. But as fluids press equally in every direction upon those bodies that are immersed in them, this pressure, unlike the perpendicular pressure of solids, acts equally on every part; so that one force is counterbalanced

by another, and the actual weight sustained in the line of gravity, is no more than what arises from the weight of the body.

Although the barometer is admirably calculated to shew the different degrees of atmospheric pressure, it forms a very imperfect weather glass, as the change of weather generally depends more upon the electrical state of the air, than upon the variation of its density.

The irregularity of atmospheric pressure that is constantly indicated by the barometer, appears to arise out of those chemical or electrical changes which are constantly taking place in the atmosphere amongst the particles of this chaotic mass.

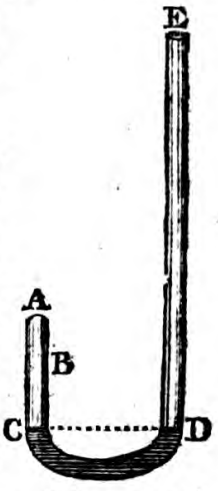
It has been already stated, that no chemical change can take place without a correspondent change of temperature; therefore, if a chemical union be effected amongst some of the elastic fluids of the atmosphere, through the agency of electricity, the latent heat of the gas becomes free heat, and the surrounding air of the atmosphere will be rarefied accordingly; this diminishes the atmospheric pressure upon that part of the earth's surface immediately under it, and produces a correspondent depression of the mercurial column. The variable winds within the temperate zones of the earth, may be explained on similar principles.

The *elasticity* of air arises out of its great

capacity for caloric, which renders it indefinitely expansible.

If the whole atmosphere were of uniform density, like that which we breathe, it would be very easy to ascertain its altitude; for the weight of air to that of quicksilver being as eleven thousand to one, and a column of quicksilver two feet and half high, being equal in pressure to an atmospherical column of similar base, the whole height of the atmosphere, if it were of uniform density, would be rather more than five miles; but as air is indefinitely expansible, and the influence of the earth's attraction keeps constantly diminishing, it seems impossible to ascertain its limits.

The space which air occupies is reciprocally proportional to the compressing force.



Pour a small quantity of mercury into the bent tube A E, and it will rise to C D; then stop it up at A, that no more air may escape out of that part of the tube. It is now evident that a column of the whole atmosphere, equal to the area of the tube, rests on the surface of the mercury D, and is counterbalanced by the elasticity of the air in the short column A C, which presses with equal force on the surface C. Now fill D E with quicksilver to the height of thirty inches, or till

it is equal in weight to the pressure of the atmosphere, and double the weight of the atmosphere rests on the surface D, which will force the fluid to the point B, equal to half the height of the column A C; so that the density of the air in the short tube is doubled when the pressure in the long one is increased in the same proportion. As the space occupied by air is proportional to the pressure, and as the pressure of the upper parts of the atmosphere upon the lower becomes less according to the different heights, it necessarily follows, that the air in the higher parts of the atmosphere must be rarefied to a very great extent.

Now, supposing the atmosphere to diminish in density according to the different heights, it is calculated that at the height of three miles and half it would be twice as rare as on the earth's surface; at seven miles, four times as rare; at fourteen miles, sixteen times; twenty-one miles, sixty-four times; twenty-eight miles, two hundred and fifty-six times, and so on.

Newton estimates that a cubical inch of the air we breathe would be so much rarefied at the height of five hundred miles from the surface of the earth, as to fill a hollow sphere equal in diameter to the orbit of Saturn.

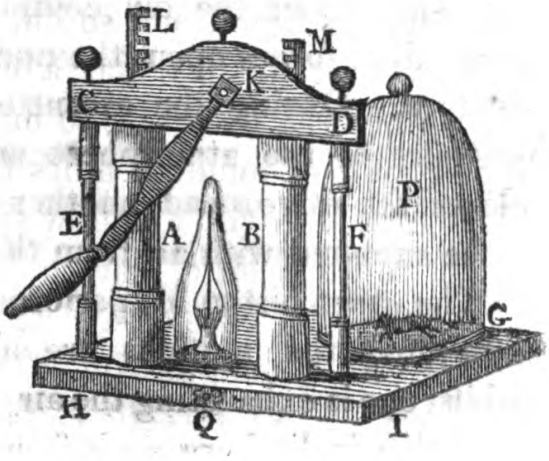
The elastic force of air acts in right lines, so that when the compressive power is removed, it diverges in all directions as from a common

centre. When small globules of air are rarefied, they still preserve their spherical form. Glass globes and soap bubbles are formed by the elasticity and equal divergency of the particles of air. If a bladder, containing a portion of air, be laid before a fire, the accession of active heat amongst the particles will produce an equal divergency, until it is completely inflated.

The *air pump* is an indispensable machine in experimenting on the density and elasticity of air. It was originally invented by Otto Guericke, about the year 1654; but it was soon afterwards greatly improved by Boyle and Hook, and recently brought to great perfection by Cuthbertson and others.

This machine is particularly useful in prosecuting all pneumatical enquiries; it affords us an opportunity of examining both the chemical and mechanical properties of air, and shews us the great importance of the atmosphere in the general economy of nature.

The construction of the common air-pump is as follows: A and B are two brass cylinders, fastened down to the base of the machine H I, by



the head and columns C E, D F ; P is the receiver, which stands on a circular brass plate with a small hole in the middle, through which the air passes in a brass tube, from the recipient to the bottom of the cylinders A B. Near the bottom of each cylinder is a valve of oiled-skin opening upwards ; and above are two others in the pistons that move up and down in the cylinders, by the toothed rods L M. These rods fall into a toothed wheel sunk in the block C D ; and this is turned backwards and forwards on its axis K, by means of the handle of the pump.

When the handle is moved, one of the pistons is raised, and the other depressed ; consequently a rarefied space is formed between the upper and lower valve in one of the cylinders, which receives the air that rushes from the recipient through the tube and lower valve, to restore the equilibrium. Suppose L the elevated piston ; when the motion is reversed, M, the other piston, ascends, and L is depressed ; in its depression, the elasticity of the air contained between the two valves forces open the uppermost valve and escapes. During the ascent of the piston, the pressure of the atmosphere on the upper side closes the valve, and another void is produced to be supplied with air from the receiver.

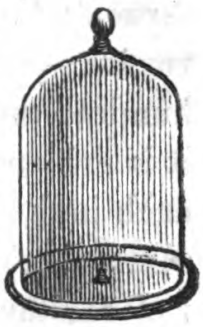
The other piston M, performs the same operation ; but the motions are alternate ; so that whilst one is exhausting the air out of the receiver, the other is discharging it from the cylinder.

By a continued action of the pump, the density of the air keeps diminishing in the receiver until its elastic power is not able to force open the lower valve; then the effects of the machine cease, and any further operation at the handle becomes useless.

When the experiment is performed, the air is again admitted to restore the equilibrium, by opening a small screw Q, which communicates with the air channel and receiver.

A quicksilver gage and small receiver are placed over a second hole in the base of the machine, which communicates with the large receiver. The gage points out by the different altitudes of the mercurial column, the degree of exhaustion, or the relative density of the air contained within it.

What has been stated of the *pressure* and *elasticity* of air may be further demonstrated, by the following experiments with the air-pump:



If a glass receiver be placed upon the pump-plate, the *pressure* of the air within is equal to that without; and the vessel may be easily moved in any direction; but if the equilibrium be destroyed by pumping out a portion of the interior air, then the exterior pressure is greater than the interior resistance, and the glass is pressed down on the pump-plate by the difference of these forces. If we suppose the open part of the

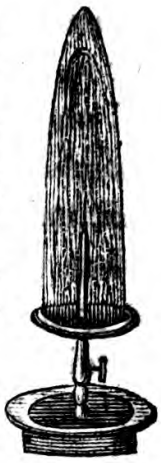
receiver to contain an area of thirty-six square inches, and the whole of the air to be exhausted, the pressure of the atmosphere upon the receiver being fifteen pounds on a square inch, it would be pressed down with a force of five hundred and forty pounds in the line of gravity; but the actual pressure on the glass itself would be equal to the number of square inches on its whole surface, multiplied by fifteen.

Galileo's principles of atmospheric pressure are confirmed by the following experiment of Otto Guericke.

The instrument is a hollow sphere, composed of the semispheres A and B, with a stop-cock and tube C, that screws into the pump-plate: when the interior air is exhausted, the exterior presses the semispheres so closely together that it requires very considerable power to separate them. Suppose the mouth to contain twelve square inches, and it requires a force of one hundred and eighty pounds to pull them asunder, it is evident that the pressure is fifteen pounds on each inch, which corresponds with the force of atmospherical pressure ascertained by a mercurial column.

If a tall receiver be placed over a brass plate and jet-pipe, connected with the air-pump by a stop-cock and tube; when the air is exhausted out of the receiver, unscrew the whole from the

pump-plate, and introduce the lower end of the tube into a vessel of water; on opening the stop-cock, the pressure of the atmosphere on the surface of the water will drive it through the jet into the receiver, forming a pleasing jet d'eau, until the density of the interior and exterior air become equal.

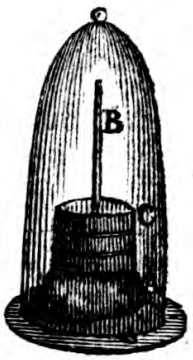


A fountain may be produced without the air-pump, by fixing a burning taper in the tall jar, which decomposes the oxygen contained within it, and thereby diminishes the density of the air: bring the end of the tube into a vessel of water, and it will be driven into the jar, until an equilibrium obtains between the densities of the interior and exterior air.

If three tapers are employed instead of one, and these be fixed at equal distances from each other upon an upright rod contained within the receiver, the uppermost taper will be extinguished first, then the middle one, and lastly, the lowermost. This shews that the oxygen contained in atmospherical air, in all cases of combustion, remains longest undecomposed nearest to the surface of the earth, and that when a room is on fire, it may be the most safely entered in a crawling position; and as free heat constantly ascends, from the levity of its parts, there will likewise be less influence from its effects.

The *elasticity* of air is experimentally demon-

strated by tying up a very small quantity of air in a bladder, and placing it under the receiver of an air-pump. As the air is exhausted the bladder gradually distends, until it is completely inflated by the elasticity of the included air; when the exterior air is admitted, the volumne is gradually reduced until an equal density is obtained.



The bladder A, contains a small quantity of air, placed in the frame B, with the weight C resting upon it. On exhausting the air out of the receiver, the air tied up in the bladder expands with such elastic force as to raise up eight or ten pounds weight.

If a glass bottle with a small tube in its neck, be half filled with water and placed under a receiver, when the air is exhausted, and consequently the pressure or resistance taken away from the extremity of the jet, the elasticity of the air in the bottle pressing on the surface of the water drives it through the tube to a considerable height.

The power of a fountain of this kind may be greatly augmented without placing it under a receiver, by using an injecting machine to condense the air in the upper part of the globe, which will expel the water with a force

proportional to the difference of the densities of the internal and external air.

The *air gun* has its effects from the elasticity of condensed air which is contained in a hollow sphere, or an exterior cylinder. When the air is sufficiently compressed by the syringe, it is retained in the exterior cylinder by a valve placed between the condenser in the butt of the gun and the air cylinder; so that if the trigger be drawn, the fall of the cock opens a communication with the interior cylinder, and a portion of condensed air rushes in behind the ball, and expels it with considerable velocity. A number of balls may be discharged with one condensation; but the elastic force of the air is diminished by every discharge.

The *peculiar advantages* which are derived from the *chemical* and *mechanical properties* of the ATMOSPHERE, are so remarkably striking and so manifestly point the power, wisdom, and design of the first great cause, that it would be unpardonable to dismiss this part of our subject without adverting to them.

By means of the oxygen of the atmosphere, we may be said to "live and move, and have our being." It constantly enters the lungs of animals,

and in a few moments this element disappears, when the remaining portion of air is expelled, unfit for the further purposes of animal respiration, until it has again obtained a sufficient portion of oxygen.

This air is likewise the general means of obtaining and supporting combustion; it chemically combines with the inflammable body, and light and heat are evolved. Yet from the wonderful economy of nature, we find no diminution of oxygen; the extensive surface of vegetation is constantly pouring its unbounded stores of this gas into the atmosphere, to make up for that which has been destroyed by other processes of nature.

Even vegetable life greatly depends upon some of the elastic fluids of the atmosphere, which become purified by its influence, and rendered more fit for the purposes of animal life.

Numberless changes which take place amongst the particles of inorganic matter, are wholly dependent upon the composition of the air we breathe; even the surface of the earth itself, from which we obtain all the supplies of vegetation, is derived from the operation of the atmosphere. Water, heat, carbonic acid, and other chemical agents contained in the surrounding medium, combine with the surfaces of the rocks that compose our globe, and in the process of time, produce a stratum of sand, gravel, or loose

earth, which receives the seeds of lichens, mosses, and other imperfect vegetables that are constantly floating in the air. These seeds vegetate; the plants die; and the decomposition of this vegetable matter mixed with loose earth, constitutes an imperfect soil, which becomes more, and more improved by similar processes, until the accumulated stratum is capable of retaining the roots of the towering oak, and its rich soil becomes fitted for perfect vegetables and all the purposes of man.

If we had no atmosphere the face of nature would be wonderfully changed; we should have entire darkness, till the sun appeared above the horizon; then it would burst forth with an excess of splendour that would be unsupportable; which would continue unchangeable, till the rotation of the earth shut us out from its influence, and then we should be instantly precipitated again into the abyss of darkness. Even during the time that the sun was above the horizon, we should be deprived of light if we turned our backs towards him; and only that portion of objects would be visible on which the direct rays fell; but the atmosphere reflects the sun's light in every direction, and the whole surface of a body is rendered visible by the rays which fall upon it. This elastic and transparent medium reflects rays of light for some time before sunrise and after sun-set, when the direct rays could

not reach the observer on account of the convexity of the earth's surface; and this not only adds the blessing of light to our natural day, but modifies its intensity and gradually prepares us for its direct influence.

The atmosphere being an elastic fluid, is densest near the earth's surface; and as transparent fluids refract light according to their density, light is therefore refracted in the horizon more than in the upper parts. The horizontal refraction forms an angle of about thirty-four minutes, and as the mean diameter of the sun only subtends a visible angle of thirty-two minutes, the sun, by means of this refraction, is seen when it is actually below the horizon.

The atmosphere is the general receptacle of exhaled vapour; there it accumulates and forms clouds, from which the rain descends to fertilize the earth and produce springs, rivers, and seas, for the various purposes and necessities of man and inferior animals.

We are even indebted to atmospheric pressure for the water which we obtain on the surface of the earth.

Water has such capacity for latent heat that it would pass into the state of vapour as soon as it ceased to be ice, if the repulsive agency of caloric were not restrained by the pressure of the atmosphere, until it has obtained a temperature of about two hundred and twelve degrees.

If water, at the temperature of seventy degrees, be placed under a well exhausted receiver, it immediately begins to boil, and the steam which escapes from the surface condenses on the side of the receiver.

It is the varying pressure of the atmosphere that causes water to boil at different temperatures. When the atmospheric pressure is diminished until the mercurial column in the barometer stands at twenty-eight inches, the water will boil at two hundred and nine degrees of the thermometer; at thirty-one inches, the temperature of boiling water is two hundred and fifteen degrees; but at twenty-nine inches and half, the mean state of atmospheric pressure, the water boils at two hundred and twelve degrees; which is the mean temperature.

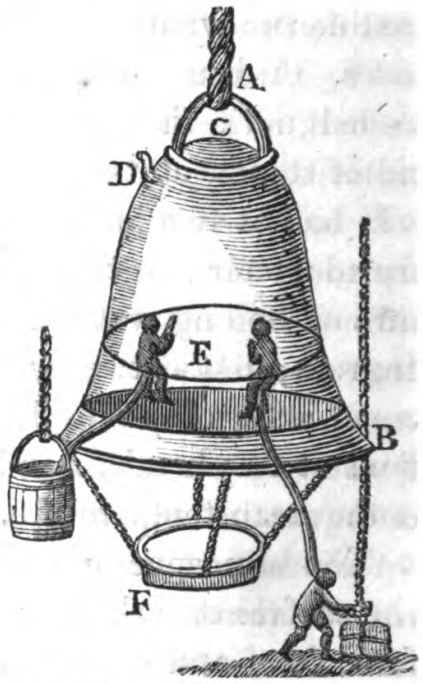
The atmospheric pressure raises water from the surface of wells, to the height of about thirty-four feet, and without which, pumps would be useless.

The action of bellows whether for the purpose of fluxing ores and metals, or for the convenience of the chamber, are dependent upon the elasticity of air and the oxygen contained therein.

The *diving-bell* is a machine which has been occasionally employed for very useful purposes, and is equally dependent upon air and water. This machine is contrived to supply divers with air, whilst they descend to considerable depths

in the sea to effect their various objects; its form very much depends upon the purpose to which it is applied.

Dr. Halley was the first who attempted this hazardous enterprize, and employed the following apparatus.



The bell A B, is about three feet wide at the top, five feet at the bottom, and about eight feet high, containing nearly eight hogsheads, or about sixty-three cubic feet of air. Its sides are loaded with lead, to make it sink in the water; and at the top of the bell C, is a thick glass, to give light to the interior of the machine. Towards the middle E, is a seat for the divers to rest upon, and a broad iron rim F, is suspended by chains from the bottom of the bell, which not only serves for the divers to stand upon, but likewise to keep the machine in an upright position.

The divers have strong globular caps with flexible tubes, fastened to their heads, and circular glasses in front to admit light when they are out of the bell fixing tackle, or effecting other purposes, at the bottom of the sea.

The impure air is let out of the bell into the water, by the valve D, and the bell is supplied with fresh air by barrels open at the lower end, containing about sixty-three gallons each, which are loaded with lead and let down close by the side of the machine. The divers get hold of a flexible tube that is fixed to the top of the barrel, and by turning a stop-cock, the air escapes into the bell, by the pressure of the water at the lower end of the barrel.

It has been already stated, that the space occupied by air is reciprocally proportional to the compressing power; therefore, if a column of the atmosphere be equal to a column of water thirty-four feet high, the weight of twice that column of water would compress it into half the space; consequently the bell at the depth of thirty-four feet would be half full of water; at sixty-eight feet, two thirds, and so on in a similar proportion, until the machine would be almost wholly occupied by it, and the divers consequently lost; but by means of the supplying barrels, they not only receive fresh air for their existence, but likewise increase the quantity of air in the bell to such an extent, that the water is wholly driven out of the machine.

Bodies that balance each other when weighed in the atmosphere, lose their equilibrium in vacuo. For if a cork and a piece of lead be balanced in air, the cork will be heavier than the lead under

an exhausted receiver. When bodies are weighed in air, each loses of its weight the weight of the air which it displaces; and as the cork displaces more air than the lead, there is more weight restored to it, when the fluid medium cannot operate against it.

The times of the descent of bodies of different specific gravities, vary by the resisting medium of the atmosphere. In an exhausted receiver a piece of thin paper will fall with the same velocity as a piece of metal; for the influence of attraction is according to the quantity of matter; and as the resisting medium is withdrawn, the gravitating power and velocity become equal in the two bodies.

The importance of the atmosphere cannot be more strikingly illustrated than in the propagation of sound. The elastic influence of air is the ready vehicle by which our ideas are usually transmitted to one another; without it, the organs of speech would be useless, and we should be deprived of the means of converse, which affords such delectable enjoyment to rational minds.

Sound is produced by the vibration of elastic bodies, and is transmitted to the ear by shells or pulses of air, something similar to waves of water; only in the former case concentric shells are produced, in the latter concentric circles.

If a stone be thrown into a pool of water, the fluid where it enters becomes elevated by its

pressure; but it instantly begins to subside by the power of gravity; and as fluids press equally in every direction, a portion of the surrounding water is elevated into a circular wave; this subsides in its turn, and produces another wave, by pressing on the contiguous fluid, and so on, until the whole force is lost and an equilibrium obtains.

When an elastic body is put in motion, the vibration presses on the air in its immediate vicinity, and produces a condensed shell, which by diverging equally in every direction, acts upon the adjoining and surrounding particles, and produces a second shell or pulse; this produces a third, and so on; but from the want of perfect elasticity in the air, the shells gradually lose their density until the whole influence is lost. If the ear be situated within these pulses, it receives the impression of sound with an audibility according to the density. The condensation of air by the organs of speech, the mouth of a flute, or the pipes of an organ, produces pulses of air as well as an elastic vibration.

Though air is the usual vehicle of sound, yet it is transmitted through water and elastic solid bodies. Dr. Franklin says, that with his ear under water he heard stones struck in this medium at the distance of a mile. The scratching of a pin on the end of a piece of hard timber, may be distinctly heard at the distance of fifteen or twenty feet, if the ear be brought in contact with the opposite end.

The power of vibratory motion and the transmission of sound may be sensibly felt by the following easy experiment.

Take about a yard of thick string and tie it in the middle, to the top of a common fire poker, then twist the two ends round the fore-finger of each hand, and suspend the fire poker, placing the end of the fore-fingers in each ear. When the iron is struck by a key, or any other metallic body, the vibration will be very sensibly felt, and the successive impulses will be heard with a force and tone like that of a large bell.

Sound is calculated to travel with a velocity of one thousand one hundred and forty-two feet in a second, and its audibility decreases as the squares of the distance from the object of vibration.

Supposing the velocity of light to be considered as instantaneous, the distance of a discharged cannon, or an electric cloud, may be easily determined by counting the number of seconds that take place between the flash and the report; this difference multiplied by one thousand one hundred and forty-two feet, gives the distance in feet.

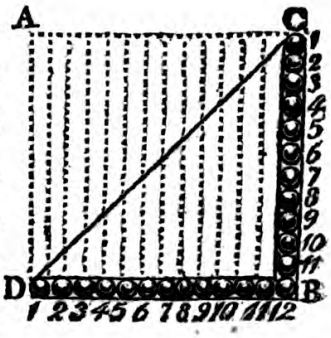
WATER.

THE mechanical properties of fluids differ very considerably from those of solids. The influence of a solid is according to the quantity of matter multiplied into its velocity, and when left free, it is directed in the line of gravity; but the force of water, or any other inelastic fluid, does not depend upon the quantity, but upon the height and base of the column, and its pressure is equally exerted in every direction.

The pressure of water upwards is equal to its pressure downwards at any given depth, and the pressure increases with the depth.

As the particles of water press equally every way, the pressure against the sides of a vessel will be according to the depth from the surface of the water.

If the column of water C B, be supposed to consist of any number of particles acting upon each other in a perpendicular direction, the first particle presses on the second by its own gravity;



the first and second press upon the third; the first, second, and third, upon the fourth, and so on; the pressure of the column increasing with the depth of the fluid.

This pressure is equally exerted either upwards, downwards, or laterally, inasmuch as there is perfect mobility amongst the particles of the fluid, and action and re-action are equal and contrary.

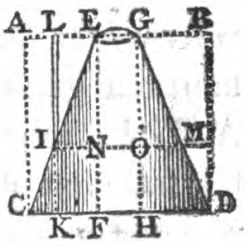
If we consider the pressure on the sides of the vessel in an arithmetical series, it will be equal to half the pressure on the bottom; for as every particle in the bottom of the preceding figure sustains eleven others, the pressure will be $11 \times 12 = 132$; but the sum of the series for the pressure on the side of the square is sixty-six, which is half one hundred and thirty-two; so that the pressure on D B, the base of the square A B, is equal to the sum of the pressures on both sides of the columns.

As the pressure of water is equal in every direction; if two apertures be made of similar dimensions, one in the side and the other in the bottom of a vessel, equal quantities of water will flow from each in equal times, provided the height of the column above each aperture be the same. The height of the column belonging to the vertical aperture is reckoned from the centre of the hole.

The pressure which the bottom of a vessel

sustains from the water contained in it, under every form of the vessel, is equal to the weight of a column of the fluid, the base of which is equal to the area of the bottom, and the height the same with the perpendicular height of the water.

If the base and height of the vessel A D, fig. 2, be equal to the base and height of the vessel A F, fig. 1, the pressure on the base of the second will be equal to the pressure on the base of the first; although the capacity, or quantity of fluid contained in the first is much greater than in the second.



If I K L M, fig 1, be equal to E G F H, fig 2, the pressures on the bases L M and F H, are evidently equal; and if I M and C D be drawn at equal distances from the respective bases C D, E F, there will be the same pressure upwards on every part of the lines, and the pressure at I, where the column of water touches the side of the vessel, is equal to the pressure of any other column in the line I M; therefore, a column extending from I to L, would be equal to N E, and the pressure on the side of the vessel at I, from the motion of fluids in every direction, has a re-action equal to the weight of the column N E = I L; which makes the pressure of I K, on the base of the vessel, equal to the whole column E F.

This principle will equally apply to any other lateral point in C E; so that the whole taken together, makes the pressure of the water on the bottom C D, equal to the pressure on the bottom of the cylinder E F.

It might be shewn that the lateral re-action at I, is equal to the weight of the column N E, by inserting a glass tube in the side of the vessel; for the pressure upwards at I, would fill up the tube to the surface of the vessel.

According to the preceding principle, if C D be a hogshead full of water, four feet high, containing one hundred gallons, and the small tube A B, be four feet high, inserted in the top; on filling the tube, which will not contain a pint of water, the pressure on the bottom and sides of the vessel will be as great as if the sides of the hogshead were carried up four feet higher, and another hundred gallons of water added.

The effects of the hydrostatic bellows practically show that the influence of water depends much more upon the altitude of the column than the quantity employed.

A B are two thick boards joined with strong leather; a small tube C D is fixed to the under board, and communicates with the interior of the machine. When this apparatus is employed,

water is poured in at the upper end of the tube C, and the pressure of the column of water C D raises a very considerable weight, placed upon the upper board A.

The mechanical force of the hydrostatic bellows is as the square of the diameter of the small tube to the square of the diameter of the circular boards that are connected by the leather.

If we suppose the diameter of the boards to be twelve inches, and the diameter of the tube one inch, the power of the machine would be as one hundred and forty-four to one; but if the tube C D be thirty-four feet high, and be filled with water, the pressure on the base of this column would be twelve pounds; therefore the power of the machine would be $12 \times 144 = 1728$ pounds; or a column of water C D, thirty-four feet high, and one inch in diameter, would balance one thousand seven hundred and twenty-eight pounds placed upon the board A. Thus, by increasing the altitude of the tube, the power of the machine increases accordingly.

This principle has been made the foundation of a very ingenious and useful machine, which is employed for many purposes where great power is required: it is called the *hydraulic press*.

Two cylinders of different diameters, according

to the power required, are connected together by a tube; the larger contains a solid piston, which moves in a collar of leathers, fitted in the upper part of the hollow cylinder. The small cylinder contains a forcing piston, which, by the action of the handle, presses on the water that is admitted by a valve from a small reservoir, and drives it through the tube of communication into the larger cylinder, where it presses against the bottom of the piston or ram, and impels it upwards with a prodigious degree of force. When the machine is to be relieved, or the power taken off, another valve is opened, which suffers the water to flow back again into the reservoir, and the ram descends by its own gravity.

The principal difference between the hydrostatic bellows and hydraulic press, consists in the action of the piston and lever, instead of a small cylinder of indefinite height.

The diameter of the large cylinder upon a working scale, is twelve inches; the forcing cylinder sometimes only a quarter of an inch, and the advantage of the handle twelve to one. An engine of this description, with the power of two men, has an active force, or pressure, of upwards of two thousand four hundred and seventy-eight tons. This machine has been publicly exhibited in Hyde Park, and its power employed before many hundred persons in pushing down large trees.

The power of a *small model* of the hydraulic press, having the ram an inch in diameter and the forcing piston a quarter of an inch, is estimated in the following manner.

The squares of the diameters of the ram and piston are to each other as sixteen to one; this multiplied by eight, the power of the lever, gives one hundred and twenty-eight; and this again by the acting power of the arm at the end of the lever, which we will estimate at only fifty pounds, gives a force or pressure of near three tons, and has an influence equal to five hundred and thirty-three atmospheres, or to a column of water three miles and half high.

On the specific gravity of bodies. When a solid, *heavier* than water is immersed in it, the solid loses of its weight the weight of the water displaced by it.

For when a solid enters a fluid specifically lighter than itself, it displaces as many particles as are equal to its own magnitude; and these particles oppose its descent with a force equal to their pressure upwards, in a column of which the base is equal to the bulk of the solid: therefore the weight of the solid in water must be diminished by the weight of the pressure of the fluid; but as the gravity of the solid exceeds the pressure of the column upwards, it descends by the excess, losing a part of its weight equal to the repulsive force of the water.

Let E be one end of a scale beam, and B a bucket, containing a quantity of water equal to the magnitude of the cylinder A; after balancing the scale at the opposite end, immerse the solid A in the vessel of water C F; then the end with the weights, will overbalance the end with the cylinder; but when the bucket B is filled with water, being equal in magnitude to the solid, the equilibrium again obtains, which evidently proves the law.

The *relative gravity* of bodies specifically *heavier* than water, is ascertained by the preceding principle.

Suppose a piece of gold of standard purity weighs one hundred and thirty grains in air, but on being weighed in water, loses seven grains of its weight: the specific gravity of the gold to water, is as one hundred and thirty, to seven, or as eighteen four-sevenths, to one.

The purity of metals may likewise be determined in this manner: suppose a piece of gold weighing one hundred and thirty grains in air, should lose eight grains in water, or only weigh one hundred and twenty-two grains, the specific gravity of this gold to water would be as sixteen one-fourth to one.

When a solid, *lighter* than an equal bulk of water, is placed on its surface, it will sink in it,

until it has displaced as much of the fluid as is equal to its own weight; for it sinks till the pressure upwards is equal to the pressure downwards, and then the weight of the water displaced is equal to the whole weight of the solid.

Let a piece of wood float in a small glass of water; take the weight of the whole, and mark the height at which the water stands in the glass, then take out the wood, and the equilibrium will be diminished by its weight; but if water be poured in till it reaches the mark, the weight of the displaced fluid is supplied, and the opposite ends of the scale-beam will be again found in equilibrio.

The *specific gravity* of solids *lighter* than water, may be ascertained in the following manner.

Weigh the body in air, then fasten it to the bottom of the water-scale with a stiff wire, and take the weights out of the opposite scale, allowing for the weight of the wire. Now place the body in a vessel of water, adding weights to the water-scale, till the balance is equal; then add the weights of the two scales together, and divide the weight of the body in air by this sum, which will give the specific gravity of the body compared with water.

Suppose a piece of wood should weigh sixty grains in air, and when it is fastened to the water-scale, it requires seventeen grains in the same scale to balance it. $60 + 17 = 77$ and $60 \div 77 = .78$, the specific gravity of the wood.

To find the *specific gravity* of *fluids*, it is only necessary to find the different degrees of density, which may be readily effected by weighing a solid in them specifically heavier than the fluids; the difference of weight, shews the comparative gravity.

If a solid in air weighs one thousand four hundred and sixty-four grains, and in water loses four hundred and forty-five grains, the weight in water is $1464 - 445 = 1019$. Place one thousand and nineteen grains in the weight-scale, and weigh the solid in a spirituous fluid. Suppose it should require thirty-eight grains in the weight-scale to restore the equilibrium; then $445 - 38 = 407$; so that the loss of weight of the *same bulk* of the two fluids is as 445 to 407, or as unity to .914; which is the specific gravity of the spirituous fluid, water being one.

The *hydrometer* is a simple and useful instrument, that ascertains the relative gravity of spirituous fluids by comparing *different bulks* of fluids, which have the same weight.

The neck A B is graduated, to shew the different depths to which the instrument descends in fluids of different gravities. B is a bulb to which the neck is fastened, and C a weight hung from the bottom to keep the instrument in a upright position, at A is a small shoulder, to receive the weights which are laid on the instrument, to adjust it to any particular depth.

As the resistance of fluids is according to their density, it is obvious that the instrument will sink deepest in those fluids that are the lightest, and this variation will be shewn by the scale or neck. When the instrument is immersed, the fluid which is displaced is equal in bulk to that part of the instrument which is covered by it, and in weight to the whole instrument. Thus the relative density, or the strength of two or more spirituous fluids may be compared, by observing the rising or sinking of the neck of the instrument.

Table of Specific Gravities.

SUPPOSING RAIN WATER 1.

Platina, - -	22.060	Elm, - - -	.617
Refined gold,	19.342	Ash, - - -	.732
Quicksilver, -	13.580	Fir, - - -	.545
Refined silver,	10.534	Cork, - - -	.244
Lead, - - -	11.352	Distilled water,	.993
Native copper,	7.800	Spring water, -	.999
Iron, - - -	7.788	Sea water, - -	1.030
Tin, - - -	7.291	Nitric acid, - -	1.403
Zinc, - - -	7.190	Sulphuric acid,	1.846
Ivory, - - -	1.829	Oil of turpentine,	.874
Oak, - - -	.923	Alcohol, - - -	.836

The *motion of water* relates to the force and construction of engines, pumps, water-wheels,

fountains, and every other description of hydraulical machine.

These machines have their effects from the gravity or pressure of water, the elasticity of condensed air, or from the force or pressure of a solid on its surface.

The most simple and natural action of water arises out of its gravity, which produces a horizontal surface, when the fluid is left free and undisturbed, whether it passes through the regular curve A B, or the irregularly bent tube C D.

Mongolfier has extended an ingenious principle of our countryman, Whitehurst, and made the gravity of water subservient in raising it very considerably above its own level, by a machine, called the hydraulic ram.

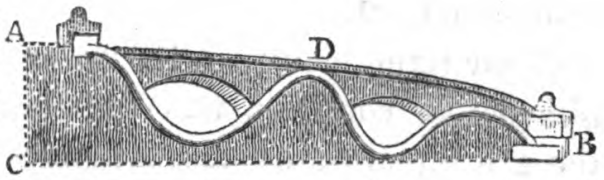
Suppose a valve placed in the lowest part of the curve A B, and so exactly balanced, that when the water is at rest within the tube, the valve falls open and it begins to run out; the current of water that is thus induced, becomes an additional power, which closes the valve again, and drives the water above the level A B, into an air vessel, and from thence to the place to be supplied.

Whilst a constant supply of water is conducted into the tube at A, the machine will continue its operation; but a great loss of fluid is sustained,

for as soon as the descending impulse of the current is destroyed by the gravity of the water in the opposite leg, it becomes quiescent; the valve falls open, and a portion of water runs out to generate a fresh impulse or current in the descending leg. From the constant noise that is produced by the opening and shutting of the valve, the French call this machine the belier, or water ram.

The natural gravity of fluids affords a convenient means of supplying water where the situation will admit of it.

Suppose A, the source or spring, and B the reservoir



to be supplied; the water may be conducted between the two places by pipes, even if hills intervene, provided the top of the highest part does not exceed the height of the source; by this means the water will flow into the reservoir in the same manner as if it had been conducted by the more direct course A D B.

The velocity of water through tubes is uniformly as the height of the source, if a due allowance be made for friction or the rubbing of the particles of the fluid against the sides of the tube, in its passage through it. In the figure, C B represents a horizontal line from the reservoir, and A C the perpendicular height of the source.

The *syphon*, or *crane*, is an instrument dependent upon the gravity of fluids, and is very conveniently employed in emptying vessels and carrying water over the summit of hills, provided the height does not exceed that to which a column of water will rise by the pressure of the atmosphere.

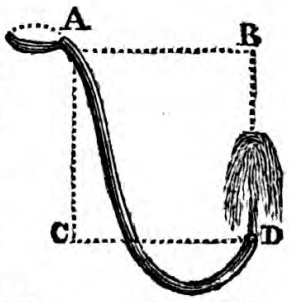
If the bent tube **E F**, be filled with water, and be inverted with the ends suspended horizontally, the fluid will not run out, if the perpendicular height of the legs be less than thirty-four feet; for the gravitating power of the water is equal in each leg, and its descent is opposed by the superior power of the atmospheric pressure. But if the legs are of unequal length, like those in the syphon **I H**, and the end of the shorter be immersed in a vessel of water, on exhausting a portion of the air out of the syphon, the water will immediately ascend, from the force of atmospheric pressure, and flow from the lower extremity of the tube.

If this syphon, with unequal legs, were filled with water and inverted, the atmosphere would press equally at each extremity; but the gravity of the two columns being unequal, the equilibrium

is destroyed, and the water will fall through the longer leg.

The third figure has a small tube attached near the lower extremity, and a stop-cock a little above it. The upper end of the small tube is conveniently placed for the application of the lips, to draw the air out of the syphon, when the lower end is stopped up with the end of the finger. The stop-cock serves to retain the instrument full of the fluid, so that it may flow as soon as the cock is opened.

Natural and *artificial fountains* are formed by the *gravity* of a column *of water*, or the pressure of *condensed air* on its surface.



The water which descends from a reservoir at A, would acquire such velocity from its gravity as would carry it up to an equal height at B, if the tube were continued to that point; but as it terminates at D, it will issue from the extremity with a velocity equal to that which it would have obtained in falling from A to C, so that the velocity of fountains is in proportion to the perpendicular height of their extremities; but the resistance of the air at the lower extremity breaks the column of the fluid, disperses it, and destroys its force, which prevents the water from reaching the height of its source.

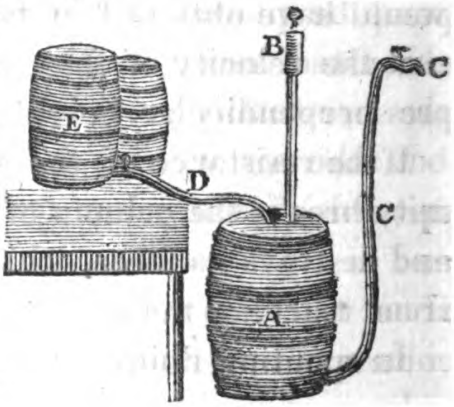
In spouting fluids, or when water issues from

an aperture in the bottom or side of a cylindrical vessel, the velocity of the fluid is equal to that which a body acquires by falling perpendicularly through a space, equal to the distance between the surface of the water and the aperture in the vessel. As the velocity of bodies in falling through a given space, is according to the squares of the distance fallen through, so the velocity of water, issuing from the bottom or perpendicular sides of vessels, is as the square root of their height or pressure.

The *elasticity* of *condensed air* acts as a moving power upon the surface of water.

This influence is very conveniently employed in the construction of several hydraulical machines. When water is to be delivered from the extremity of a tube or jet, a velocity nearly uniform is obtained, by forcing the fluid previous to its delivery into a reservoir or air vessel, where the re-action of the condensed air expels the water with a very uniform velocity, provided the supply is kept up tolerably well.

The *elasticity* of *air* is employed, as a moving power, in the following apparatus, for raising liquor from the cellar to the bar of taverns:



A is the receiving

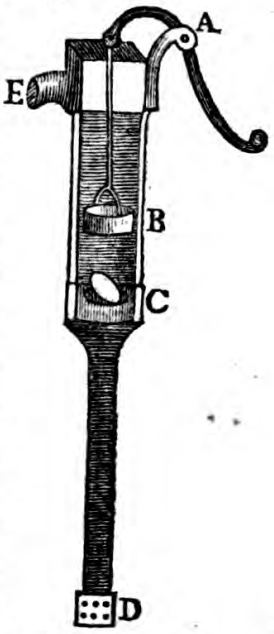
vessel, which is made perfectly air-tight, and sunk about half its depth in the floor of the cellar. The leather hose D, is occasionally used to empty the butts of liquor E, into the receiving vessel, by the natural gravity of the fluid. After the receiver has been filled to a certain height, the communication is stopped, and air is injected into the upper part of the receiving vessel, by means of the forcing piston and pipe B, which is placed in the bar. The pressure of the condensed air on the surface of the liquor, drives it through the tube C, and it is drawn off from the cock. When the velocity of the fluid diminishes, it may be instantly renewed by three or four strokes with the handle of the forcing piston. The ordinary machine which is now used for raising beer is a common pump.

Pumps. This useful and domestic machine was invented about 120 years before the Christian Æra; but it was greatly improved after the atmospheric pressure was discovered by Galileo.

If the lower extremity of a model of a common pump be placed in a vessel of water, under an exhausted receiver, the want of atmospheric pressure totally prevents the supply.

If the air were exhausted out of a cylinder upwards of thirty-four feet long, on placing one end in a well of water, the fluid would rise to about thirty-four feet; or till the gravity of the column of water became equal to the pressure of a column of the atmosphere of the same base.

The *common pump* depends on the following principles for its construction and operation:



The pump A D, is composed of two cylinders of unequal diameters: about twenty-four feet from the surface of the water in the well, is placed the valve C, which opens upwards. The piston B moves up and down by the action of the handle, and contains another valve, which likewise opens upwards. When the piston B is raised up by the depression of the handle of the pump, the air contained between the piston and lower valves B and C, expands and diminishes the pressure on the lower lid, which suffers a portion of the denser air, between C & D, to enter the rarefied space B C, and restore the equilibrium. The returning action of the handle again exhausts an additional quantity of air from C D, until the atmospherical pressure drives the water through the lower valve into the larger cylinder, to the height of about thirty-four feet above the surface of the water in the well; and if the lower valve be placed at the distance of twenty-four feet from the surface, the water will consequently stand ten feet above it.

When the piston descends, the weight of the water upon the lower valve closes it, and the fluid is forced through the upper by the sinking of the

piston; so that when the piston rises, the water that presses on its upper surface is lifted up into the reservoir, and flows out of the spout.

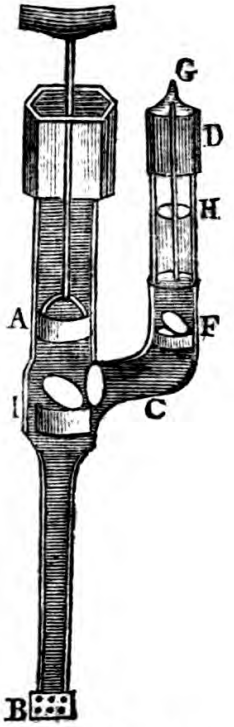
If the pump be in good condition, the water will stand in the cylinder close to the spout, and be ready to flow out on the first stroke of the handle.

As the ordinary force of the pump is confined to that of a man, a pump in a deep well cannot supply so much water, by the same power, in the same time, as one that is placed in a shallower. If a man be able to raise forty gallons of water in a minute, in a cylinder five inches in diameter, from a well twenty feet deep; in a well forty feet deep, the cylinder must only be three inches and half in diameter to support the same weight of water, which will only supply twenty gallons a minute. In a well sixty feet deep, the diameter of the cylinder must be two inches and three-quarters, and the quantity of water pumped up will be about thirteen gallons a minute. If the well be one hundred feet deep, the diameter of the cylinder must be two inches and a quarter, and the quantity discharged will be only eight gallons a minute.

To make a pump work with the least possible force, it is very necessary to make the lower cylinder of such dimensions as to fill the upper cylinder with water, as fast as the piston rises, otherwise there is not only the column of water

to be lifted by the handle, but also the atmospheric pressure at the rate of fifteen pounds upon each square inch of the area of the base of the cylinder.

The *forcing pump* raises water to the height of about thirty-four feet, by the pressure of the atmosphere, and it is then driven to a considerable height by the pressure of a solid piston on its surface: it differs from the common pump by having an air vessel D F, into which the water is forced through the tube C, and from whence it is driven out by the elastic force of the condensed air through the aperture G, with a velocity proportional to the degree of ærial compression.

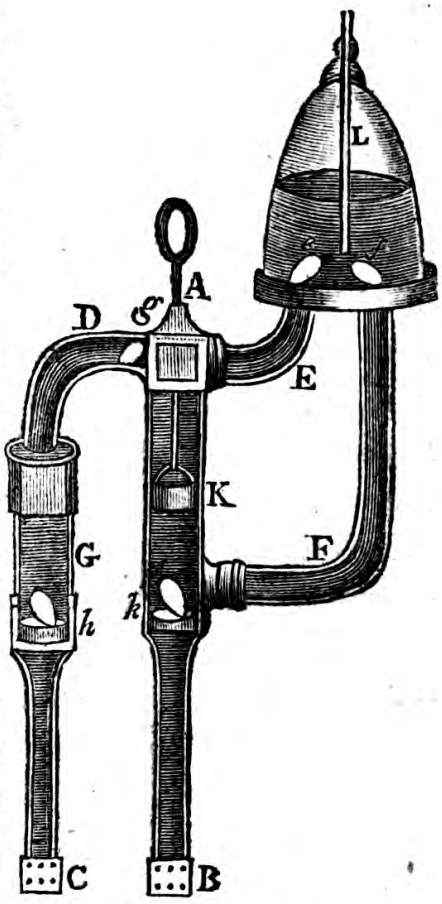


Engines of this description are peculiarly convenient for supplying reservoirs on the tops of houses with water; for watering gardens, and many other ordinary purposes.

De la Hire's Pump has the operation of a common lifting and forcing pump, but is very limited in its application, as it cannot be employed in raising water from a greater depth than thirty-four feet.

The cylinder A B, is the same as the forcing pump, with the conveyance pipe F, to carry

water into the air-vessel L. There is also another conveyance tube E, which conducts the water from the cylinder D G C, into the air-vessel.



The piston A K, works air-tight in the collar of leather A, and when it descends it shuts the valve k, and drives the water up F into the air-vessel, like the common forcing pump. If the air be exhausted out of the adjoining tube D G C, which communicates with the upper part of the cylinder A K, and the height D C, be less than thirty-four feet, the atmospheric pressure will force the water through the valve g, into the cylinder; and when the piston rises, the column of water upon its upper surface, closes the valve g, and is forced through e, into the air-vessel: thus a constant supply of water is obtained, both in the ascending and descending stroke.

Engines for *extinguishing fire* have different constructions: the most ordinary form is by the

action of pistons in two cylinders, which drive the water into an air-vessel; from whence it is delivered by a flexible tube of leather, with a metallic jet at its extremity.

Bramah has formed a fire engine upon a different construction; the principal part consists of a large short cylinder, placed horizontally, in the centre of which a metallic plate moves on its axis, through a small arch, by the action of the handles. This plate fitting close to the inside of the cylinder, has the operation of a piston, and drives the water that has previously entered, by the pressure of the atmosphere, out of the cylinder into the air-vessel, from whence it is carried off in the ordinary way.

PRACTICAL MECHANICS.

THE action and efficiency of machines, whether simple or compound, depend upon some moving force, of which there are various kinds: as the gravity of a weight; the elasticity of a spring; the pressure of air; the muscular power of men, or horses; the motion of wind vanes, and water-wheels; or the elastic force of steam.

The influence of solids depends on their weight and velocity; and the force of elastic fluids is according to their compression or condensation, as we have already explained.

The power of animals is dependent upon the contraction and relaxation of their muscles, which admits of the following mechanical explanation: The bones are levers, the joints fulcra or props, and the force is applied by the muscles, which are generally attached to the bones by the intervention of tendinous cords.

When a muscle contracts in the direction of its fibres, it becomes thickened; when the muscle relaxes itself, it is merely passive; for the fibres being extremely flexible, can have little or no

effect in separating the parts to which they are attached. This separation is generally performed by the action of other muscles, and sometimes by elastic ligaments.

Bones form levers of the third order, where the two opposing forces are on the same side of the prop. In general the insertion of a muscle is much nearer to the prop than the point of action, and the obliquity of its direction still gives it a greater mechanical disadvantage; but it is much more convenient in the animal economy to produce a great contractile force than a great extent in the original motion.

For instance, when the arm is raised by the exertion of the muscle of the shoulder, a very strong contraction takes place in the muscle; but the action is only continued through a very short space: if the contractile power had been weaker and more extensive, the shoulder must have been higher, in order to give it sufficient purchase, and this projection would have been both ungraceful and inconvenient.

It has been calculated that the immediate force of the double-headed muscle that bends the arm, is equivalent to about three hundred pounds; and that the muscles which raise the lower jaw in man, have a power equal to five hundred pounds, and in beasts of prey it is much greater.

The daily work of a labouring man of middle age, and in good health, is used as a standard of comparison with other powers.

It is estimated that a man can raise ten pounds ten feet high, in a second, for ten hours a day; or six thousand pounds, one foot high, in a minute, for the same time.

The actual velocity of a man's motion must vary according to the mode in which his force is applied; but we consider the velocity to be such as to give the greatest effect, under the peculiar circumstances of the machine.

For a short time, a much greater effect than the preceding may be produced by an extraordinary exertion. For instance, a man weighing one hundred and sixty pounds, could run up steps at the rate of three feet in a second, for half a minute; but this is an effect five times greater than what he could continue for the whole day.

When the hands are chiefly employed either in turning a winch or pumping, it is only possible to exert a double, or at most, a triple action for a minute or two. A machine may enable a man to raise a hogshead of water in a minute to the height of ten feet for a whole day; yet it is possible to work it so rapidly for a single minute as to raise double the quantity, or to raise a single hogshead to the height of twenty feet.

When *weights* are *to be moved* from one place to another, different modes are adopted. Some place the weight on their heads, others on their shoulders, and some on their backs; but all must bend in such a way, that the centre of gravity

arising out of the weight and body, may fall between the feet.

If the weight be carried on a hand-barrow by two persons, and be placed at equal distances from each extremity, the men will support an equal portion of it; but if the weight be placed nearer one end than the other, the load will be distributed in the same way that the poles are divided by the centre of the burthen. For instance, if the weight were three hundred pounds, and it were placed at the distance of one foot from one man, and two from the other, the first would carry two hundred, and the second one hundred pounds.

If *porters* ascend a hill, or a flight of steps, the distribution of the load will remain the same, provided that the centre of gravity of the weight be in the plane of the poles. But if the weight consists of a large body placed on that plane, the centre of gravity being above it, the inclination of the poles materially changes the distribution of the load, since the pressure will always be determined by the distance of the ends of the poles, from a line passing perpendicularly through the centre of gravity; so that if the elevation were sufficient, the whole weight might rest on the lower person.

The daily work of a *horse* is equal to five or six men. Its immediate force is something greater; but it cannot support the labour of

more than eight hours a day, when it draws with a force of two hundred pounds; or of six hours when drawing with a force of two hundred and fifty pounds, and walking two miles and half an hour.

It is calculated that a London dray-horse, of ordinary strength, will raise thirty-three thousand pounds, one foot, in a minute, for eight hours a day; and a man of ordinary power can raise six thousand in the same time; so that the power of the horse is five times and half greater than the man. This is the foundation on which the comparative power of steam engines is estimated.

To obtain the greatest force of a horse, it is of considerable importance to incline his traces on the line of draft; for the acting power of the animal may be represented by a line passing from one of his hinder feet to the shoulder, and the resisting power, by a second line from the hind foot, perpendicular to the line of traction. The length of the acting arm may be considered as constantly the same; but the resisting arm of the lever is less in an inclined than in a horizontal line of traction. There are different opinions with respect to the degree of inclination; it may be theoretically demonstrated that an angle of about eighteen degrees, is the most advantageous.

This inclined traction is not only advantageous in obtaining the greatest force of the horse, but is likewise correspondent with the force of the

horse's shoulder; and also draws the *wheels* of carriages over stones and other obstacles with less force than when the line of draft is horizontal.

The acting force in overcoming obstacles on the road, may be represented by a line drawn from the summit of the opposing body perpendicular to the line of traction; and the resisting force, by a line drawn from the same point at right angles, to a perpendicular spoke of the wheel.

In wheels of the same diameter, the resisting arm of the lever is constantly as the height of the obstacle; but the acting arm is longer in an inclined than in a horizontal line of draft.

In order to employ the greatest advantage of traction, in the construction of four-wheeled carriages, the inclined line ought to be directed to a point half way between the wheels, or rather to a point immediately under the centre of gravity of the carriage; and such a line would always pass above the axis of the fore wheels.

The present practice of making broad wheels *conical*, has obviously the disadvantageous effect of producing very considerable friction at each edge of the wheel, when the carriage is moving in a right line; for if such a wheel moved alone, it would always describe a circle about the vertex of the cone to which it belongs.

If broad wheels were made *cylindrical*, with their rolling surfaces a little convex, a consider-

able portion of power would be saved at the source.

When wheels are narrow, a slight inclination of the spokes appears useful in keeping the wheels more steady on their axles, than if they were exactly vertical; and when the road gives the body of the carriage an inclination, by which it is thrown more on the lower than the upper wheels, then the inclining spokes possess a vertical position, and the wheels are more able to support the increase of weight. This inclination of the spokes likewise throws the mud and dust of the wheel at a greater distance from the carriage. The greatest loss of power which carriages sustain, arises from the prodigious friction produced by bad roads. If legislative interference would compel the use of cylindrical wheels of different breadths, and axles of different lengths, according to the tonnage, instead of being buried in ruts, we might reasonably expect, from this improved practice, to find the public road nearly smooth and even.

Wind is employed as a moving force to act upon the sails of wind-mills, that a rotatory motion may be given, by proper machinery, to the mill-stones that grind the corn.

The quantity of work effected by a wind-mill is very variable, and must obviously depend upon the strength and duration of the currents of air which constitute wind.

A large wind-will may on an average, be calculated to work about eight hours a day, and the whole effect is equal to the labour of about thirty-three men, or six horses, if we consider the force of twenty-five square feet of sail equal to one man.

It has been theoretically demonstrated that the greatest possible pressure of the wind upon a given oblique surface at rest, tending to put it in motion in a direction perpendicular to that of the wind, is obtained when the vane forms an angle of about seventy-four degrees with the axis. The mechanical power of such a pressure is estimated from a combination of the intensity of the wind with the velocity of the surface acted upon.

In this, as well as in many other cases, the practice materially varies from the theory; and it is found that much more power is obtained when the oblique angle varies from one extremity of the arm to the other.

The sails of the common wind-mill are frequently made to change their situation according to the direction of the wind, by means of a small wheel, with sails, which turns round whenever the wind strikes on either side of it, and drives a pinion that turns the whole machinery.

The sails of the wind-mill are sometimes made to furl and unfurl themselves according to the velocity of the wind, by means of a revolving

pendulum, which rises to a greater or lesser height, according to the velocity of the sails. This addition is to prevent the injury which the flour suffers from too great a rapidity in the motion, or any other accident which might happen in a mill of a different construction.

The inclination of the axis of a wind-mill to the horizon, is chiefly intended to allow room for the action of the wind at the lower part, where it would be weakened by the sails coming too nearly in contact with the building, if they stood perfectly upright.

When it is necessary to stop the motion of a wind-mill, a break is applied to the surface of a large wheel, so that the friction which is thus produced, operating with very considerable force, keeps constantly diminishing the velocity, until it loses all its motion.

The common mill for grinding corn is composed of two circular stones, of silicious grit, placed horizontally. The upper one revolves with considerable velocity, and is supported by an axis passing through the lower one that is variable at pleasure. A mill-stone five feet in diameter, usually makes ninety revolutions in a minute.

The corn is shaken out of a funnel or hopper, by projections fixed on the revolving axis, which strike against an aperture in the bottom; by this means the grain is regularly supplied from the

hopper, and falling through the hole in the upper stone, it is easily admitted between them both, and reduced to flour by the friction which acts upon it.

The lower mill-stone is slightly convex, and the upper one somewhat concave, so that the corn passes over rather more than half the radius of the stone before it begins to be ground. After it is reduced to powder, it is discharged at the circumference of the mill-stones, by the centrifugal force and the slight convexity of the under stone.

The surface of the stones is cut into small grooves, that they may act more readily and more effectually upon the corn. The resistance in grinding wheat has been calculated at about $\frac{1}{35}$ of the weight of the mill-stone.

When the velocity is increased too much by the action of the wind, the corn is sometimes driven through the mill-stones without being ground; this is prevented by the centrifugal force of two balls, similar to those employed in the steam-engine, which causes a lever to ascend, that brings the upper mill-stone a little nearer to the lower.

The bran, or husk, is separated from the flour, by sifting it over a cylindrical sieve, placed in an inclined position, and turned by proper machinery.

The gravitation of *water* is employed with great economy and advantage as a moving power, to

give motion to different kinds of machinery, through the agency of a water-wheel.

In whatever way we apply water, the mechanic power which it possesses is measured by the product of the quantity multiplied into the height from which it falls.

For example, a hogshead of water capable of descending from a height of ten feet, possesses the same power as ten hogsheads falling from the height of one foot: and a cistern filled to the height of ten feet above the aperture, possesses one hundred times as much power as the same cistern filled to the height of one foot only.

If we apply this principle to an overshot-wheel, we shall find that the velocity, or breadth, and the magnitude of its buckets, is perfectly indifferent with respect to the value of its operations. For, suppose the stream to enter the buckets with the uniform velocity of the wheel, the quantity of water in the wheel at any one time, and consequently the pressure, must be inversely as the velocity; so that the produce of the force into the velocity will be the same, however they may be separately varied. The general velocity of the surface of a wheel is between three and six feet in a second, according to the size.

When the fall of the water will admit it, an *overshot-wheel* is far preferable to any other; but when the fall is too small for an overshot-

wheel, the operation of a *breast-wheel* is the most valuable. When we have only the advantage of a river or stream of water, running nearly in a horizontal direction, an *undershot-wheel* must be constructed.

When an overshot-wheel is employed, the water is delivered into the buckets near the crown or top of the wheel; and in order to avoid the resistance which is occasioned by stagnant water below it, it is desirable to turn the stream backwards upon its nearer half, so that when the water is discharged, it may run off in the general direction of its current.

The breast-wheel partakes of the same principle and construction as the overshot-wheel; the water is delivered into buckets, upon its periphery, at about half the altitude of the wheel; and supposing the quantity of water to be the same, the power would be relatively as the difference of the square of the radius and diameter of the wheel.

The overshot and breast-wheel receive a considerable increase of power by fixing a sweep or arched channel nearly in contact with the lower part of the wheel, which serves, in some measure, to confine the water in the buckets until they come very nearly to the bottom.

In an undershot-wheel, or when the stream strikes nearly horizontally against the float boards on the under part, its velocity ought to be equal

to half the velocity of the stream; and the float boards should be so placed as to be perpendicular to the surface of the water at the time they rise out of it. Only half the depth even of the lowest float board, should be below the surface of the water, and not more than from three to five should be immersed at the same time, according to the size of the wheel.

To determine the effects of any force employed in machinery, we must not only consider its magnitude, but also the velocity with which it can be brought into action; so that the ultimate value is expressed by the joint ratio of power and velocity.

Thus, for example, if we had a corn-mill in which we wished the mill-stone to revolve with a certain velocity, and to overcome a given resistance: now, supposing that this effect could be obtained by a combination of wheels from the source of motion, if the velocity of the motion at the source be reduced one half, we must double the diameter of one of the wheels, by which the force is communicated, in order to give the mill-stone the desired velocity; and thus we must introduce a mechanical disadvantage, which can only be compensated by a double intensity in the force, at its origin.

STEAM AND STEAM-ENGINES.

THE *steam-engine* is the most magnificent effort of mechanical invention, and in a commercial country like this, which depends for its pre-eminence, upon the extent and perfection of its arts and manufactories, the indefinite power that may be always obtained by this noble machine, must render it an object of great importance in a national point of view.

The power of the steam-engine depends upon the highly *elastic force of steam*.

It has been already explained, that the specific gravities of both solids and fluids depend upon the agency of heat in an active and latent state. Water at the temperature of two hundred and twelve degrees, under the ordinary pressure of the atmosphere, is converted into steam of the same temperature, with a specific gravity one thousand eight hundred times less than that of the water, and has an *elastic force* equal to the pressure of the atmosphere.

If the steam be retained in the vessel in which it is generated, the active heat accumulates, and the elastic force of the steam increases according to the following statement:

Elastic force of Steam.

Temperature pressure.	Atmospheric.	Pressure on a Square Inch.	Inches of Quicksilver.	Feet of Water.
212°	= 1	= 15lbs.	= 30	or 34
250°	= 2	= 30	= 60	or 68
275°	= 3	= 45	= 90	or 102
294°	= 4	= 60	= 120	or 136
309°	= 5	= 75	= 150	or 170
344°	= 8	= 120	= 240	or 272

The force that may be thus obtained from the elasticity or steam is of unlimited extent, which renders the steam-engine of more importance to large manufactories than any other description of power.

A considerable number of horses could not be conveniently employed; the force of wind is dependent and uncertain; and the influence of water is limited to the quantity and velocity; but the elastic power of steam is constant in its operation and indefinite in its extent.

The power of a horse is equal to the power of five or six men: the work effected by the mean power of a wind-mill, is equal to about thirty horses; and double this force is much more than the generality of water-wheels possess; but steam-engines are made with a power equal to one hundred and fifty horses, even if they were constantly at work. As a horse cannot work for

more than eight hours a day, an engine of this description can effect as much labour as four hundred and fifty horses, because it may be kept constantly in motion.

The first idea of the *steam-engine* is found in a small tract, called "A Century of Inventions," published by a Marquis of Worcester, in the year 1663. In this work, amongst many other contrivances, he proposes to obtain prodigious power from the agency of steam; but no contemporary record exists to illustrate or verify his description of what we may presume to call a steam-engine; or to inform us where and in what manner it was carried into effect. His description is short and obscure; but from what is stated, it seems probable that the force of his engine was derived from the *elasticity* of steam only; and that the *condensation* of steam, by cold, formed no part of his contrivance.

About thirty years afterwards, Captain *Savary* contrived a steam-engine, in which he employed both the *elasticity* and *condensability* of steam: he formed many engines of this description; and in the year 1696, published a full account of his steam-engine, in a small tract, called the "Miner's Friend."

Savary's engine consisted chiefly of a boiler, a condensing cylinder, and an upright tube, which was connected with the condensing

cylinder. The top of this cylinder was kept within thirty-four feet of the surface of the water that was to be raised. When the stop-cock opened the communication with the boiler, the steam entered the condenser and expelled the atmospherical air through the upper part of the perpendicular tube; a valve in the lower part, opening upwards, prevented its return. Water was then thrown on the outside of the condenser, which produced a void in the interior, that was instantly occupied by water raised up from the well by the pressure of the atmosphere, and a second valve opposed its return. The next and last operation was to expel the water from the cylinder, and drive it out from the top of the upright tube, by admitting the elastic force of the steam upon the surface of the column that was contained in the condenser; when the whole of the water was driven out, the steam was again condensed, and the water admitted and expelled as before.

This appears to be the first employment of steam to form a vacuum, and raise water without the assistance of pistons, as in common pumps; and must be considered as an important step in the progress of steam engines.

The principle and operation of this machine being so very simple, it is even now applied in particular cases with great advantage; but it

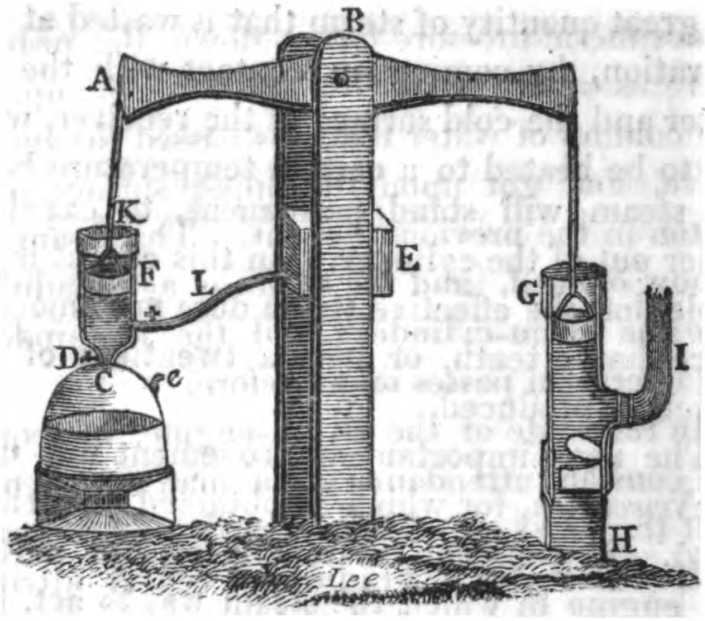
must have been very inconvenient and dangerous in raising water from any considerable depth; for the receiving vessel must always be placed within thirty-four feet of the surface of the water, otherwise it could not be filled by the pressure of the atmosphere; and the pressure or elastic force of the steam must effect the rest. Suppose this engine to have been employed in raising water from a mine only a hundred yards deep, the pressure of the atmosphere would raise the water thirty-four feet; and the elastic force of the steam would have to raise it up the perpendicular tube two hundred and seventy feet; which, according to the preceding table, would be equal to eight atmospheres, and would require steam of a temperature of three hundred and forty-four degrees. This would press with an elastic force of one hundred and twenty pounds upon every square inch of the interior of the boiler; and as the inner surface of the boiler must necessarily contain many square feet, it is difficult to imagine how boilers could be made strong enough to afford any tolerable security, when this machine was employed to raise water in the operation of mining, where it was chiefly employed. However, it is most probable that the whole depth of the mine was divided into lifts, so as not to endanger the bursting of the boiler.

Another objection, on the score of economy is,

the great quantity of steam that is wasted at each operation, by coming in contact with the cold water and the cold surface of the receiver, which has to be heated to a certain temperature before the steam will stand permanent, to expel the water out of the cylinder. In this case it is probable that the effective steam does not amount to more than a tenth, or even a twentieth of that which is produced.

The next important improvement was made by *Newcomen*, for which he obtained a patent, in 1705. It consisted in separating the parts of the engine in which the steam was to act, from those in which the water was to be raised, the weight of the atmosphere not being employed for the purpose of pressure, but for displacing the air, and forming a vacuum by condensation.

Newcomen was thus enabled to dispense with steam of great and dangerous elasticity, to work with moderate heats, and to remove at least some part of the causes of wasteful and ineffectual condensation. To him we are indebted for the introduction of the steam-cylinder and piston, and for their connection with the pump, by means of the transverse beam, with its rods and chains, to which we might add several other subordinate contrivances, that do great credit to his ingenuity.



The beam A is placed between two large standards, and turns on its axis B, with a piston and rod fastened to each end, which work in the cylinders D K and G H. The vessel C is partly filled with water, and kept boiling, which fills the upper part of the boiler with steam. The piston rod of the pump G H, is made very heavy, or loaded with iron to make it descend with facility, when the steam is admitted through the steam-cock D into the cylinder D K. When the piston F has ascended to the top of the cylinder, partly by the weight of the loaded piston, and partly by the elasticity of the steam, the cock D is shut, and the water-cock in the tube L is opened, which suffers a jet of cold water from the reservoir E to enter the cylinder and condense the steam that is contained within it. Now the

atmospheric pressure forces down the piston F, and raises the piston G of the water-pump, with the column of water that has passed through the valve, and got upon the upper surface of the piston in the previous descent. The steam-cock is now opened, and the steam is again admitted into the steam-cylinder; and the remainder of the operation passes on as before.

In this state of the steam-engine, it required the constant attendance of a man to open and shut the cocks at proper intervals, to admit steam and cold water. Traditional report attributes the invention, by which the engine was made to perform this work itself, to the ingenuity of an idle boy, who was placed upon this duty; it was however perfected by Henry Beighton, in 1717, and who likewise improved several other parts of the engine.

To prevent the bursting of the boiler, by any extraordinary expansion of the steam, a regulator or safety valve is placed in the top at e, which is forced open and suffers the steam to escape, when it has acquired a greater degree of elastic force in the boiler than is necessary for the operation of the engine.

The condensation of the steam in the cylinder of Newcomen's engine, was neither instantaneous nor complete; for the water which was injected had its temperature raised considerably by the heat of the steam; consequently, it could only

reduce the last portion of steam to its own temperature, and still suffered it to retain a considerable portion of elasticity: even at one hundred and eighty degrees only, steam is capable of supporting a pressure equal to half the weight of the atmosphere. It was found that the working force of the engine did not amount to more than seven pounds upon each square inch of the piston; and, at the same time, a very considerable portion of steam was wasted by cooling the cylinder at each condensation.

From this time, to the year 1769, there seems to have been no material improvement in the structure of the steam-engine, which still continued to be known by the appellation of Newcomen's, or the atmospheric engine; when, fortunately for the arts and manufactories of this country, Mr. Watt, then a mathematical instrument-maker, at Glasgow, undertook the repair of a model of a steam-engine belonging to the University; and finding that the quantity of fuel and injection water required was much greater in proportion in small, than in large engines, he tried many experiments to ascertain the cause, but at this time did not obtain any satisfactory results.

Mr. Watt then began to investigate the formation of steam, under different degrees of pressure, and to ascertain the quantity of heat employed. By a very simple experiment with

a Florence flask, he found that steam, under the ordinary pressure of the atmosphere, occupies one thousand eight hundred times more bulk than the original space of water.

He then constructed a boiler to shew, by inspection, the quantity of water evaporated in any given time: he also determined the quantity of coals necessary to evaporate a given quantity of water.

He now applied this boiler to the working model, and found that the quantity of steam expended at every stroke, exceeded many times what was sufficient to fill the cylinder, and deducing from thence the quantity of water required to form as much steam as would supply each stroke of the engine, he proceeded to examine how much cold water was used for injection, and what heat it gained; which, to his very great surprize, he found to be many times the number of degrees which could have been communicated to it by a quantity of boiling water, equal to that of which the steam was composed.

The next experiment was, to ascertain the degree of heat communicated by steam to water; when it clearly appeared that one part of water, in the form of steam at two hundred and twelve degrees, had communicated about one hundred and forty degrees of heat to six parts of water. At this time, Dr. Black had just made his important discoveries respecting latent and active

heat, which gave Mr. Watt a full explanation of the circumstance, and he then ascertained the latent heat of steam to be above nine hundred degrees.

The imperfections of Newcomen's engine were now evident. It appeared that the steam could not be condensed so as to form an approximation to a vacuum, unless the cylinder and water it contained were cooled down to less than one hundred degrees; and that at greater degrees of heat, water in the cylinder must produce steam, which would in part resist the pressure of the atmosphere. On the other hand, when greater degrees of condensation or exhaustion were attempted, by greater quantities of injection water, this was followed by a proportionate destruction of steam on refilling the cylinder.

Mr. Watt now perceived, that to make an engine in which the loss of steam should be the least possible, and the vacuum the most perfect, it was necessary that the cylinder should condense no steam on filling it; and that when condensed, the water forming the steam should be cooled down to one hundred degrees, or lower.

Hence, he concluded, that the cylinder must be kept as hot as the steam that enters it, and that if a communication were made between this hot cylinder, when filled with steam, and another vessel exhausted of air, the steam being an elastic fluid, would rush into it, until an equilibrium was

established between the two vessels and that if cold water, in sufficient quantity, were injected into the second vessel, the steam it contained would be reduced to water; and that the water, air, and any remaining portion of steam in this vessel might be exhausted by a pump, which would keep the condenser constantly in a void state, ready to receive the steam from the cylinder.

It was thus this very ingenious mechanician matured his views, and perfected his objects, before he brought them into action; and on this account he has never had occasion to alter any part of the original principles from their first establishment up to the present time. Many minor improvements were made in the atmospherical steam-engine by Mr. Watt and others. Mr. Watt himself gave a very different application of the power of steam in the working cylinder, of the more modern machines; but the advantages of time, economy, and safety, are still dependent upon his original invention.

Newcomen's engine, thus improved by Mr. Watt, was generally employed; but it was still open to his inventive genius for greater perfection.

In the preceding description of the steam-engine, it is shewn that the power of the machine is dependent upon the atmospheric pressure; consequently, upon the area of the base of the steam-cylinder. The elastic force of the steam employed, was little more than equal to that of

the atmosphere; and even the descent of the pump-piston was partly effected by the gravity of a weight connected with it; so that the great object of the steam was only to produce a partial vacuum by condensation.

When great power was required, it became necessary to make the steam-cylinder of very extraordinary dimensions, that there might be sufficient area for atmospheric pressure on the piston, as the power of the engine was wholly dependent upon this source.

Mr. Watt having ascertained the indefinite power of steam by increasing temperature, made another very considerable improvement in the atmospherical steam-engine, by introducing the pressure of steam upon the upper side of the piston, instead of the atmosphere. The top of the steam-cylinder was closed up, and the piston rod moved through a collar or stuffing box, steam tight; so that the elastic force of steam became the acting power, and the pressure of the atmosphere upwards returned the piston of the water-pump, to renew the stroke.

This, however, is only a part of what Mr. Watt saw to be necessary, in order to perfect the steam-engine. The force of steam had hitherto been used only to press down the piston, which was returned either by the atmospherical pressure on the under side, or by a weight at the opposite end of the beam; so that the power of steam was inactive during this period.

Mr. Watt's next step was the application of the elastic force of steam on each side of the piston, with an alternate vacuum in the steam-cylinder, produced by the condenser and air-pump. He thus *doubled* the power which had been previously obtained, and rendered the machine efficient in turning a crank, or obtaining a rotatory motion; which completed the great object of this noble and magnificent machine, so important to the arts and manufactories of this country.

The first engine of this description was made at Soho, in the year 1782; but the first that was publicly exhibited was at the Albion Mills, London, some short time afterwards.

Mr. Watt finding that the ordinary mode of communicating the motion of the piston-rod to the angular motion of the beam, produced very considerable friction, he invented and applied what is called the *parallel motion*, one of the most ingenious and most perfect contrivances in mechanics.

To prevent irregularities in the speed of the double power engine, arising from the varying temperature of the steam in the boiler, or the difference of resistance at different intervals in its operations, he applied a regulator, by means of the centrifugal force of two balls, connected with an upright spindle, which governed the admission

of steam into the working cylinder, and produced a uniform velocity in the machine.

There are also other ingenious contrivances for supplying the boiler with water, communicating the steam alternately on each side of the cylinder, and for ascertaining the rate of going; but these, and many other improvements, can only be conveniently explained by models of the apparatus itself.

The splendid success which so deservedly followed the labours of Mr. Watt, induced many others to attempt a claim on public patronage; amongst these, Mr. Trevithick appears to have been the most successful.

The essential difference between Mr. Watt's and Mr. Trevithick's engines, consists in the uncondensed state of steam in the engines of the latter gentleman.

Mr. Trevithick's engines are without either air-pump or condenser: when the steam has been employed in driving the piston from one extremity of the cylinder to the other, the returning stroke forces it through the waste-pipe into the atmosphere. This operation necessarily imposes greater force upon the engine, and a consequent increase of elasticity in the steam; but the power of steam is equal to any resistance; therefore all that is required in this simplification of the machine, is to render the boiler and cylinder of

sufficient strength to resist the increased pressure on the interior surface.

The economy and simplicity which is thus obtained, renders this engine very useful where an inferior degree of power is required; but it is rarely employed in any other case. The great pressure produced by the elastic force of the steam, at high temperatures, renders the employment of this engine rather dangerous: that on Watt's principle may, however, be employed with much greater security.

The various purposes to which the steam-engine is applied, renders it daily, an object of greater and greater interest. It has been employed for some years on the large rivers in America, as a moving power in navigating passage vessels, and it is now very generally employed in this country for similar purposes; and at the present moment a steam-boat is just sent out by government, up Congo River, to explore the interior of Africa. Watt's engines are generally used for the purposes of navigation, as the means of condensation are so easy; but the steam-engine is likewise employed in drawing loaded carriages on iron rail ways in some of the northern counties; and it is more than probable that it will soon become a very universal practice. Trevithick's engine is employed for this purpose; and the country will probably owe him its thanks for reducing the great number

of horses which now consume so much of its produce; particularly if public coaches and waggons are moved by this power, which many are sanguine enough to expect.

The steam-engines of Messrs. Bolton and Watt, are said to save three-fourths of the fuel formerly used; and it appears that only a quarter of the original steam is wasted.

One of these machines with a thirty-inch cylinder, will effect the work of forty horses, if they were to be relieved, and the labour were continued twenty-four hours. But, as a horse can only work eight hours a day, the engine has a power which could only be obtained from the work of one hundred and twenty horses.

When a rotatory motion is required from the steam-engine, it is obtained by a crank, or the revolving motion of one wheel round another, which has the operation of a crank. In this case a fly-wheel is indispensable, that its *vis inertia* may in some measure equalize the varying power which the wheel or crank possesses in its revolution.

Mr. Watt and many others have endeavoured to obtain a rotatory motion without the aid of a crank, by introducing steam into the hollow rim of a large wheel. A small power has been produced, but it does not seem likely at present, that sufficient force can be obtained in this manner, to render this ingenious contrivance generally useful.

The *calculation of the power* of the steam-

engine depends upon the area of the piston and the length of the stroke.

If the surface of the piston be pressed downwards with an elastic force of one hundred pounds, through the space of four feet, supposing friction and the inertia of the beam excluded, the engine would raise up one hundred pounds, four feet high, at the opposite end of the beam, which expresses the power of the machine. Let it be required to ascertain the *power* of a steam-engine, whose cylinder is twenty-four inches in diameter, and which makes twenty-two double strokes, each five feet long, in one minute; the force of the steam being twelve pounds upon every square inch.

$24 \times 24 \times .7854 = 452.4$ square inches, the area exposed to the steam; then $452.4 \times 12 = 5428.8$ lbs. pressure upon the piston, which is the weight that it is capable of raising up at each stroke. But the engine performs twenty-two double strokes, five feet long, in one minute; or $22 \times 2 \times 5 = 220$ ft. the space passed through, in one minute; so that the *power* of the engine is represented by 220×5428.8; or 1194336 lb. $=$ 2288 hhds. raised to the height of one foot in one minute. It must be noted, that no allowance has been made for friction and inertia in this calculation: about one-third of the power must be deducted on this account.

In Watt's double power engines, twenty-five

circular inches of the piston are reckoned a horse power. In Trevithick's engine, twelve circular inches is calculated to be equal to the power of a horse; the pressure on the boiler being about forty-five pounds on the inch. Fourteen pounds per hour, or four bushels of coals a day is reckoned for each horse: so that one of Watt's forty horse engines burns thirteen thousand pounds, or one hundred and sixty bushels of coals in twenty-four hours; and raises one million, three hundred and twenty thousand pounds, or six hundred tons, one foot high in a minute; or eight hundred and sixty-four thousand tons, one foot high in twenty-four hours.

OPTICS.

LIGHT constitutes the subject of this science, and is that power by which objects are rendered perceptible to our sense of sight; or the sensation produced in the mind, by the view of luminous objects.

Light, like many other objects in nature, the principle and essence of which exceed the bounds of human understanding, has long been a subject of much speculation. Descartes and Euler consider it to be a highly elastic and fluid medium, universally diffused, by which the vibrations of luminous bodies are carried to the eye; but Newton demonstrates it to be an absolute body, composed of infinitely small particles of matter, which issue by a repulsive force from luminous bodies with wonderful velocity, diverging in right lines in all directions.

The sun is the primary source of light, and the particles which issue from it pass on in a right lined direction, until they are inflected by the attraction of some other body; or refracted by passing obliquely through a medium of different density; or reflected by the intervention

of an opposing body; so that the particles are governed by the influence of attraction in the same manner as the particles of the grossest bodies.

It has been proved by the astronomical observations of Rœmer and Bradley, that light is progressive, and takes up $8\frac{1}{4}$ minutes in passing from the sun to the earth, which gives the inconceivable velocity of two hundred thousand miles in a second of time.

Rœmer deduced this velocity from his observation of the heliocentric and geocentric time of the eclipses of Jupiter's satellites. This was confirmed by Bradley's discovery of the apparent aberration of the fixed stars, which is produced by the effect of the revolution of the earth in its orbit, combined with that of the motion and progression of light.

Colours are produced by the refraction of solar light, which is one of the most striking effects of optical phænomena.

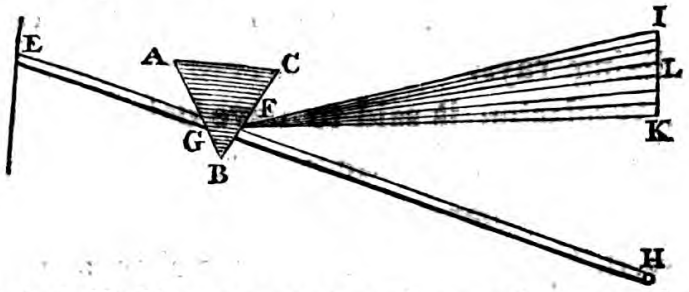
Newton discovered that white light is composed of rays of different kinds, mixed in certain proportions, and that these rays differing in colour and refrangibility, constitute a series which proceeds by gradual changes from red to violet; and that coloured bodies derive their colours, not from the bodies themselves, but from the particular property they possess of reflecting some kinds of rays very abundantly, and of transmiting or extinguishing the rest.

As, for instance, the pigment vermillion is not considered to possess any colouring principle in itself, but only to be capable of reflecting the red-making particles of light much more predominantly than any others, from which the ocular sense becomes impressed with the sensation of red.

As there is no body that wholly reflects one colour and absorbs all the rest, the predominant colour is tinged with various others, which produces that infinite variety of tints that different bodies possess.

Blackness is produced by a total absorption or extinction of all the colour-making particles of light; and as whiteness is obtained by an intimate union of the whole, black and white cannot with strict propriety come under the denomination of colours.

The Newtonian principle of colours is beautifully illustrated by the *prism*, which is a solid triangular piece of glass, through which the particles of light that constitute the sun's rays are refracted and reduced into their simple and elementary state.



Let A B C represent a glass prism, and E a small hole in the window shutter of a darkened

room, by which the pencil of rays E enters and falls on the side of the prism at G.

If the glass did not obstruct the rays, they would pass on in a straight line to H; but when the rays enter and pass out of the denser medium of the glass, they are refracted or bent towards L; those which are the least refrangible will fall nearest to the right line direction E G H; and those that are the most refrangible will be the most distant; the intermediate rays will arrange themselves according to their respective refrangibilities, and form an oblong spectrum on a white wall, variously coloured, between K and I. The least refrangible rays produce red, the next orange, then yellow, green, blue, indigo, and violet, which is the least refrangible: these constitute, according to the Newtonian theory, the seven primordial colours, and of which all others are composed.

Dr. Herschel added to this series, rays of heat, which he found to be less refrangible than the red-making rays; and Wollaston has discovered rays still more refrangible than the violet rays, which blacken salts of silver, and are called deoxidizing rays.

Dr. Wollaston is said to have determined the colours of the prismatic spectrum in a much more accurate manner than that which is usually employed, by looking through a prism at a very narrow line of light. The spectrum formed in

this manner, consists of four colours only, viz: red, green, blue, and violet, which occupy spaces in the proportion of 16.23.36 and 25, making 100 the length of the spectrum.

Some other persons have made the number of original colours even less than this.

From the extreme subtlety of light, there is much difficulty with respect to the knowledge of primordial or elementary colours. If we admit the seven primary colours of Newton, we must likewise admit seven factitious colours which impress the same sensations on the mind: for in all cases two extreme colours form the intermediate colour of the spectrum. If we take a piece of red and yellow glass, and place them together, the light which passes through is a perfect orange: or, if orange and green glass be employed, yellow is produced, and so on throughout the whole range of the spectrum.

The *rainbow* is produced by the refraction and reflection of the sun's rays in the drops of falling rain.

It is only necessary for the formation of a rainbow, that the sun should shine on a dense cloud or a shower of rain; the observer being placed between the sun and the cloud, with his body towards the sun, so that the light may reach the eye after having undergone a certain number of angular deviations, by means of refraction and reflection. The drops so situated must necessarily be found somewhere in a conical surface, of which

the eye is the vertex, and must present the appearance of an arch.

When the light first enters a drop of rain, it is refracted at the anterior, and afterwards reflected from the posterior surface; and it is again refracted on passing out of the drop to the eye. When the light is reflected from the posterior surface, its deviation never exceeds a certain angle, which depends upon the degree of refrangibility, and is therefore different for light of different colours; the density of light being greatest at the angle of greatest deviation; the appearance of a luminous arch is produced by the rays of each colour at its appropriate distance.

Those rays which are once reflected within the drop exhibit the common, internal, or primary rainbow, at the distance of about forty-one degrees from the point opposite to the sun; and those rays which are reflected twice, constitute the external or secondary rainbow, at fifty-two degrees from this point.

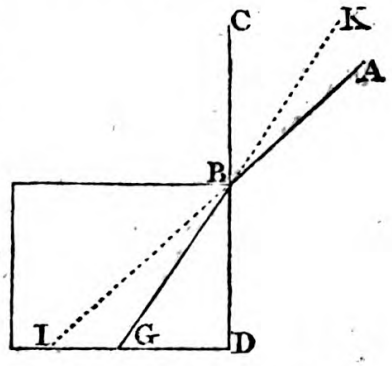
The subject of *vision* is divided into two parts, which are called refracted and reflected vision.

Refracted vision produces the different directions and effects of rays of light in passing from one medium to another.

Rays, or pencils of light, pass in right lines from luminous objects, each carrying an impression to the eye of that part of the object from which it is emitted or reflected.

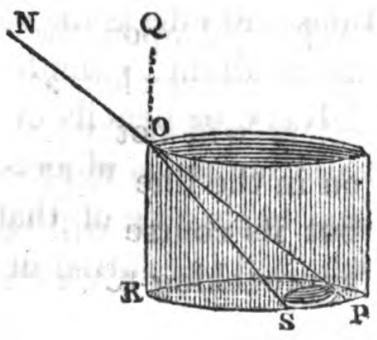
When the direction of the ray keeps in the

same medium, the object, image, and eye are found in the same straight line; but when the ray is transmitted through different media, such as air, water, glass, or any other transparent body, as it enters into each, it changes its direction, inclining more or less to the perpendicular of the medium, according to the density of the body.



If a ray of light which passes from A, in air, falls on the denser medium of the water B, it does not proceed in a right line to I; but it is attracted or drawn out of its course towards the perpendicular B D, and passes in the direction B G, which is nearer to the axis C D than the straight line I B.

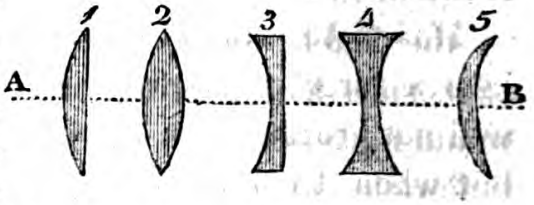
If G B be a ray of light passing from a denser into a rarer medium, or from water into air, it will not proceed in a right lined direction to K; but when it comes to B, at the surface, its course will be refracted; the ray will recede from the perpendicular D B, and pass on in the direction B A.



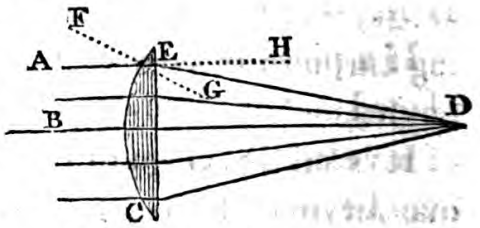
If a piece of money be placed at S, in the bottom of a vessel O R, and the eye be placed at N, so as just to observe the outer edge at P. When the eye is kept in this

situation, and the vessel filled with water, the whole of the object is distinctly seen at N, included under the angle of refraction S O P. For the rays which pass from S, in a right line, will be bent at O, the surface of the water, and fall into the eye at N, or become refracted from the perpendicular O Q.

The refraction of light in optical instruments is produced by means of pieces of glass, or chrystal, which are ground into different forms, called *lenses:* the lens changes the direction of the rays of light, either converging them into a point behind it, or diverging them after they have passed through it. Lenses are likewise employed in bringing, converging, or diverging rays parallel to each other.



The lens marked 1, is called a plano convex lens. 2, double convex. 3, plano concave. 4, double concave. 5, a concavo-convex lens, or meniscus.

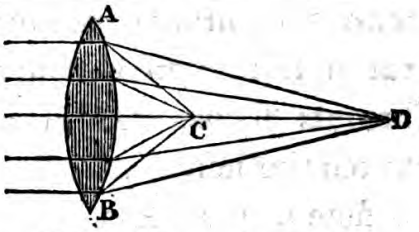


If the ray of light A E, fall upon the plano convex lens at E, it will not pass on in the line E H, but its course will be refracted in the line E D, approaching towards the axis of refraction, or

towards the perpendicular of the convex side F G. Another ray falling on C, parallel to A E, and equidistant from the axis B, will be refracted in like manner, and it will converge and meet A E in D, the focal point of the lens. All the rest of the rays between C and E will also converge to the focal point in the axis of the lens at D.

As rays passing through a plano-convex lens are converged into a focal point in the axis of the lens; if both sides be spherical, the convergency will still be greater, and the rays will meet in some point nearer to the centre of the lens.

Therefore if A B be a double convex lens, the parallel rays which fall upon it will converge at the point C,



by the double convexity of its sides; but if one of its sides had been flat, the converging point would have been extended further on to D.

Parallel rays of light falling on a convex lens, being thus rendered convergent; rays which have a disposition to meet each other, or already converge, will be rendered more convergent by passing through convex surfaces and subtend greater angles.

It is on this account that convex lenses become magnifying glasses, for every object is seen under a certain angle, formed by lines drawn from its extreme points to the eye, which is called the

visual angle; and as far as the sense of vision is concerned, the magnitude of the object depends on the apparent magnitude of the angle which it subtends.

Therefore, if converging rays, carrying the impression of an object to the eye, be compelled to pass through a convex glass, they will meet sooner, or be rendered more convergent; and the object will appear magnified by the difference of the angle which it subtends before and after refraction.

Convex lenses are called burning glasses, because the parallel and direct rays from the sun, which fall upon a convex lens, are converged into its focus, and in this point we have the united influence of all the rays that fall on the surface of the glass.

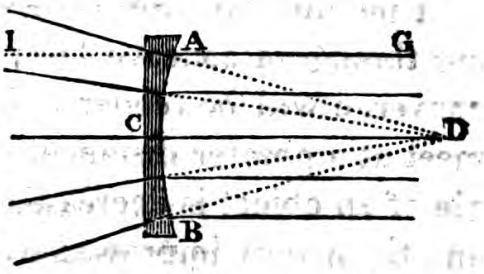
A burning glass has been formed by a lens about three feet in diameter, which fused the most refractory substances, and evaporated the densest metals in a few moments.

In every case of refracted vision a distinct impression of objects can only be obtained in the focal point of the lens.

If a lighted candle be held before a double convex lens, a distinct image, in an inverted position, will be produced in the focal point, upon a white surface; but if the candle be brought nearer to the glass, the image becomes indistinct, and is succeeded by a circular spot of light; this

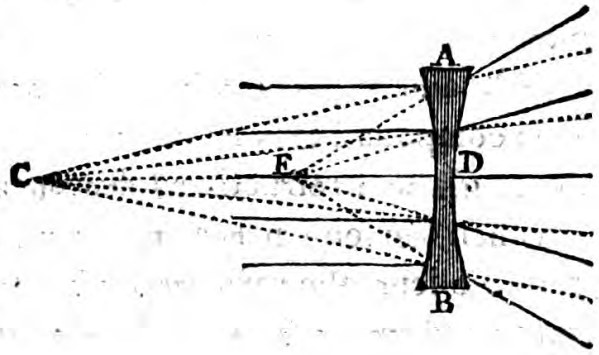
arises from the section of a cone of rays that is produced by the refracting power of the glass.

When parallel rays of light fall on a concave lens, they are rendered divergent after refraction.



If A B be a plano-concave lens, and C D the axis, let the ray A G fall upon the lens at A; then it will be refracted in passing through the glass, and diverge from the direct line G I into A D, approaching towards the perpendicular of the concave side. The ray at B being equidistant from C, will diverge in the same manner, as well as the rest of the intermediate rays, in proportion to their distance from the axis of the lens.

Therefore, as rays equally diverge from a concave surface, both in passing from or into the lens, the divergency of a double concave lens will be greater than that which is only plano-concave.



If A B be a double concave lens the divergent rays will appear to have issued from the virtual

focus E in the axis E D; but in a plano-concave lens the divergency of the rays is diminished, and the point C, at a greater distance from the lens, becomes the imaginary focus.

If parallel rays are rendered divergent in passing through a concave lens, rays which already converge will be rendered less convergent, and meet at a greater distance. Thus the visual angle of an object is decreased by a concave glass, and the eye is impressed with the sensation of a diminished object, according to the difference of the visual angle which is produced with, and without the lens.

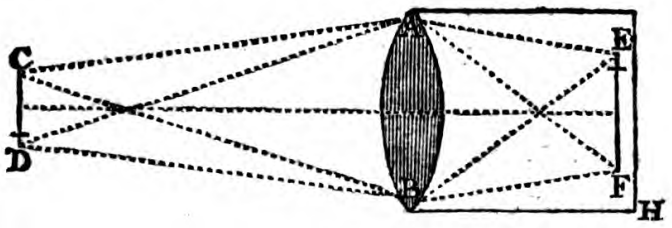
The effects of concave and convex reading-glasses, are easily explained upon the preceding principles. The convex glass increases the visual angle under which the characters are seen, consequently they appear magnified; but the concave glass lessens the visual angle, therefore the object seems to be diminished accordingly.

Lenses are formed to converge the rays of light by the union of a convex with a concave glass; by this means the imperfect refraction of the outer parts of single lenses is very much diminished, and objects are rendered more distinct. This compound lens is peculiarly useful for the object glass of refracting telescopes.

When the object is at a considerable distance from the lens, the rays which fall upon it become converged into a focal point near to it, and form

an inverted image of the object; but if the object be brought near to the lens, a magnified image is produced in the focal point, at a greater distance from it.

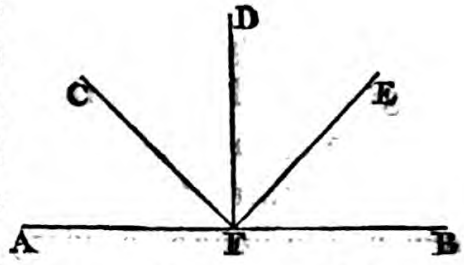
In all cases the object advances towards the lens as the image recedes; and as the object recedes, the image advances.



If A B represent a double convex lens, and C D an object at a considerable distance from the lens, the rays D A and D B, issuing from the point D, will be refracted at A and B, and converge at E. In the same manner C A and C B, proceeding from C, will converge in the focal point at F; and if we conceive an infinite number of rays passing from every other point of the object, contained between C and D, they will converge somewhere between E and F, in the foci of the lens; forming a complete but inverted image of the object. The linear magnitude of the object and image, will be relatively as their distance from the lens.

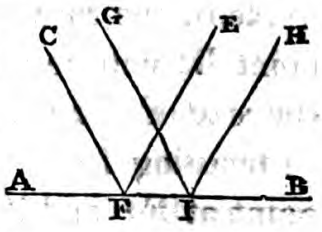
Reflected vision shews the effects produced by rays of light falling on a polished surface, and from thence returned to the eye.

Rays of light must fall either perpendicularly or obliquely upon a mirror or speculum.



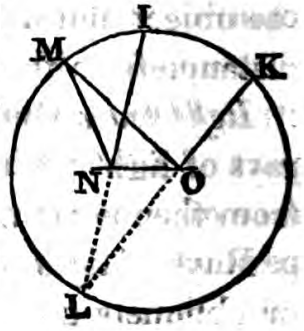
When the ray falls perpendicularly upon the surface, as D F on A B, it is reflected back again in the same direction; but when it falls obliquely, like C F, it is reflected in the direction F E, making the angle C F A = E F B. Hence this universal law of reflected vision, that the angle of incidence is always equal to the angle of reflection, whether it be reflected from plane, concave, or convex surfaces.

When parallel rays fall upon a *plane-mirror*, they still keep parallel after reflection.



If the rays C F and G I be parallel to each other, and fall upon the mirror A B, they will be reflected in the direction F E and I H, which are likewise parallel to each other.

Converging *rays* which are reflected from plane surfaces, have the same convergency after reflection as if they had passed on in straight lines.



The converging rays I N and K O having their angles of incidence equal to the angles of reflection, converge in the point M, at a distance equal to L, where the rays would have met in an uninterrupted course.

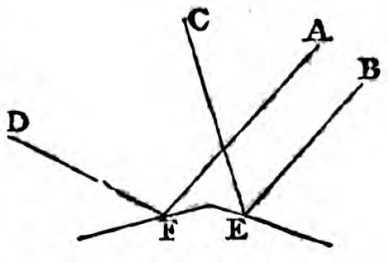
It is on this account that the image of an object seen in a plane-mirror appears of the same magnitude as the object itself; for, as the visible dimensions depend on the magnitude of the angle produced in the retina, and as the quantity of this angle undergoes no change by reflection from the plane surfaces, the visible magnitude of the object remains unaltered.

An observer sees his own image as far beyond a mirror as he stands before it, and as he moves to or from the mirror, the image will advance or recede likewise; but seemingly with double velocity, because the two motions are equal and contrary.

An object may be seen completely at any distance, in a portion of a mirror, only equal to half the size of the object; for as the image appears as far behind the glass as the object is before it, that part of the mirror on which the rays fall will be equal to only half the length and breadth of the object.

Spherical or *convex surfaces* render parallel rays divergent. Every spherical surface may be considered as composed of an infinite number of straight lines.

Suppose E F two straight lines, which form part of the convex surface of a sphere; if the parallel rays A F and B E fall upon the points



E and F, the angles of reflection will become equal to the angles of incidence; and the rays D F and E C will be rendered divergent, or will separate from each other. Therefore, if converging rays fall upon a convex mirror, the rays are rendered less convergent. It is on this account that the image of an object seen in a convex glass appears less than the object itself; inasmuch as the visual angle that subtends the object, being reflected from a convex surface, has the convergency of the angle diminished, which causes the object to appear diminished according to the difference of the visual angle before and after reflection.

The effects of reflected rays from convex surfaces are similar to those of refracted rays passing through concave lenses, and possess no actual focal point.

When parallel rays of light fall upon a *concave surface*, they are rendered convergent.

This, like the convex surface, may be considered as composed of an infinite number of straight lines.

Let G and H be two of these straight lines; the parallel rays K H and I G, which fall on these oblique lines, are reflected in equal angles through the lines H M and G L, tending towards each other until they meet in the vertex.

It may be shewn, on this principle, that rays which already converge, are rendered still more convergent by reflection from a concave surface. It is from this cause that the image of an object seen in a concave mirror appears magnified, by the difference between the visual unreflected angle, and the angle reflected from a concave surface.

The concave reflector produces effects similar to those of a convex lens in refracted vision; and it is sometimes used as a burning glass, by converging the parallel rays of the sun into the focal point of the reflector, which produces an intensity of heat according to the area of the reflecting surface.

A concave mirror only shews bodies erect when the object is placed between the mirror and its focus. If the object be placed beyond the focus, the rays cross each other, and the image is seen in an inverted position.

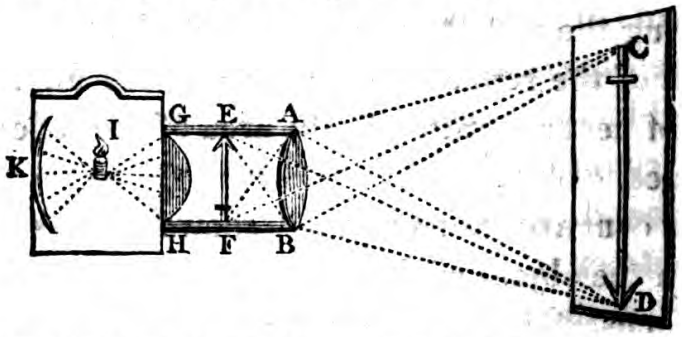
When the eye is brought into the axis of a concave reflector, and an object is presented towards the reflector, the image appears to proceed from it; and it seems not only unconnected with the mirror, but as clear and distinct as the object itself. This is made the foundation of many optical amusements and deceptions.

A *cylindrical mirror* has the effect of a plane and a concave reflector: the object is magnified in the line of concavity; but is unaltered in the

direction of the straight surface, which produces a distorted image.

The preceding observations afford but a narrow view of the principles of refracted and reflected vision; but they are still sufficient for a general explanation of *optical instruments*, and of *distinct* and *indistinct vision*.

The *magic lantern* magnifies small pictures painted upon glass, and throws a distinct image upon a white surface in a darkened room. These effects chiefly depend upon a single lens.



The lighted lamp I is placed in a square box, which has the tube G B projecting from its side. G H is a thick plano-convex lens, which strongly illuminates the object E F when it is placed in an inverted position in the tube. K is a concave reflector, which is sometimes fixed in the box to give additional force to the light, and A B is a double convex lens, placed in a moveable tube, that slides in the interior of the projecting tube G B. When this lens has received a proper adjustment, it throws the shadow of the object large and upright against the side of the wall;

and the magnitude of the shadow C D, is as much larger than the object E F, as the distance C A is greater than E A.

The *phantasmagoria* only differs from the magic lantern by having the addition of rackwork and a pinion, and winch, or some similar contrivance, to move the lens A B, through a longer tube than that which is represented by G B. Being thus enabled to place the object at different distances from the lens, a distinct image may be obtained upon a transparent medium, from one inch to upwards of six feet, in linear dimension.

The *camera-obscura* is formed by a single lens placed in a moveable tube in the front of a wooden box, containing an inclined mirror, and a piece of ground glass, placed horizontally, at the opposite end.

When the lens is presented towards any distant object, the image is converged into a focal point upon the inclined mirror; from whence it is reflected against the under side of the semi-transparent glass, and becomes distinctly visible upon the upper. This instrument affords a beautiful view of the scenery of nature, glowing in all its varied tints, and undulating with every gentle breeze.

A *telescope* is composed of two or more lenses, and is employed for viewing those objects which are scarcely distinguishable by the naked eye:

it is constructed to act either by refraction or reflection.

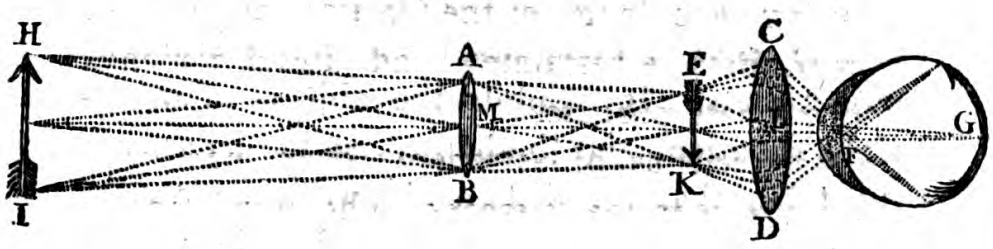
No mechanical invention has afforded more real interest to mankind than the telescope. It has greatly extended our view of creation in the unlimited regions of the heavens, and has brought us more intimately acquainted with the power, wisdom, and design of the Creator; and it is also found both entertaining and useful for many subordinate purposes.

The science of astronomy owes most of its advantages to the telescope. The great improvements which have been made in this noble instrument since its discovery, about two hundred years ago, leaves us little to be desired.

Jans, a Dutchman, is said to have been the first discoverer of the telescope; but Galileo was the first that determined its optical principles, which were soon afterwards greatly extended by Kepler, Huygens, Newton, and others. Flamsted, the first astronomer royal, with the assistance of this admirable instrument, very soon after its discovery, furnished us with a list of some thousands of stars, which had never met the observation of man since the period of his creation.

The Galilean and common refracting telescopes were employed without any material improvement, until Gregory and Newton undertook the construction of reflecting telescopes, which have been brought to their acme by Dr. Herschel.

The first telescope used for astronomical purposes, consisted of only two glasses, placed in the tube at the common distance of their foci; and as the magnifying power of the instrument depends on the difference of the focal distances of the two lenses, Huygens constructed an *astronomical telescope*, one hundred and twenty feet long.



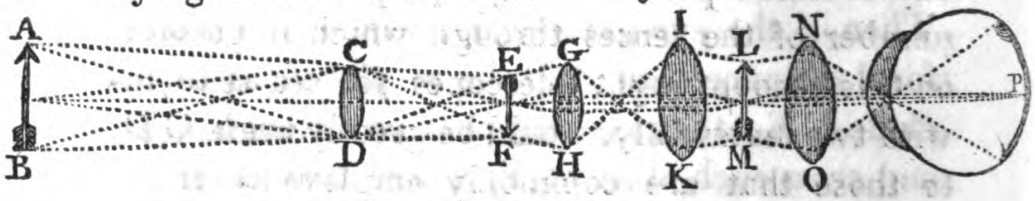
Suppose that the rays of light which issue from every part of the object H I, fall upon the object-glass A B, in passing through, the rays will be refracted and converge in the foci E K, where the inverted image of the object is formed. Then if the eye-glass C D, which is of shorter focal distance than A B, be so placed as to include E K, the rays will pass on through C D, and cross each other at F, where they enter the eye and form an inverted image of the object upon the retina at G.

The magnifying power of this telescope is as the distance of the focus of the object-glass M E, to the distance of the focus of the eye-glass E L. If the focal distances were to each other, as ten to one, the object would be magnified in linear dimension ten times; but in area, one hundred

times, which is called the magnifying power of the instrument.

This telescope produces an inverted image of the object, which is considered of no importance in astronomical observations; but for terrestrial purposes, an additional number of glasses are introduced to reverse the position.

The *land-telescope* is usually formed of three double convex eye-glasses and an achromatic object-glass. It exhibits the objects in an upright situation, and the lenses are so disposed in the tube, that the distance between any two of them may be the aggregate of the distance of their foci; so that an eye placed in the focus of the first glass will see objects upright and distinct, and magnified according to the difference of focal distance between the object-glass and the eye-glass at the other extremity.



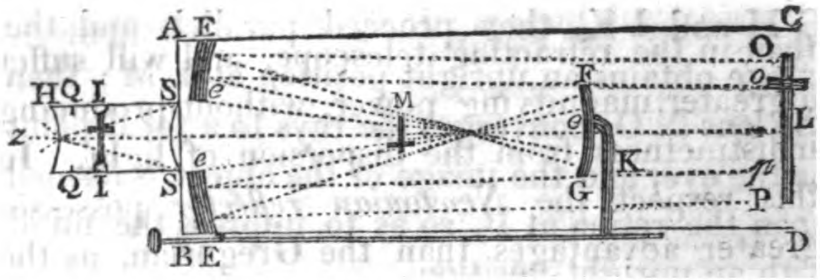
Rays from the object A B are received by the object-glass C D; and after forming an inverted image at E F, they enter the first eye-glass G H; but instead of falling into the eye, as in the astronomical telescope, they pass on to I K, another convex lens, which is placed at twice its focal distance from G H. After the rays have crossed each other, in the common focus of the lenses

G H and I K, they proceed parallel, and the image obtains an upright position at L M; then the lens N O, converges the rays to a focal point on the eye, and the image of the object is formed upon the retina at P, so as to impress the mind with an upright position.

As the addition of lenses in the land telescope does not increase the magnifying power, but only produces an upright instead of an inverted image, an astronomical telescope may be used as a land telescope, by having an additional tube with eye-glasses, made to slide into the end of the instrument. Or that which is used for the day, might be converted into an astronomical or night telescope, by taking out the useless lenses.

Whatever advantages of position may be derived from an additional number of lenses, the object loses a portion of light proportional to the number of the lenses through which it passes; on this account night telescopes for sea service, with two lenses only, would be greatly preferable to those that are commonly employed. It is true that the objects would appear inverted; but they would appear much more clear and distinct, which is a circumstance of far greater importance to the mariner.

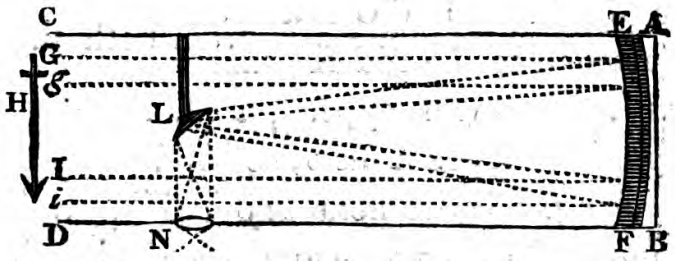
Reflecting telescopes are chiefly formed by metallic specula, and reflect the object to the eye instead of refracting it.



The *Gregorian* telescope **A B C D** is formed of a large tube, in which is placed the perforated speculum **E E**: at **F G** is a small concave reflector, fastened to the rod **K**, that is moved backwards or forwards by the nut **B**: **L** represents an object at a great distance, and its rays **O o P p** enter the instrument and fall on the larger speculum **E E**, from which they are reflected into the foci at **M**, where an inverted image is formed; but after crossing each other, the rays fall upon the small speculum **F G**; the centre of which **e**, is in the axis of the tube **z e**. From **F G** the rays would again converge in the foci **Q Q**, and form an upright image; but in order to bring the rays close to the eye, they fall upon a convex lens at **S S**, just behind the aperture in the speculum, by which the image is formed in the foci between **I I**, and from thence taken up and carried to the eye at **z**, by a lens at **H**, where the reflected image appears magnified, upright, and distinct.

The peculiar advantage of the reflecting telescope is derived from the area of the reflector, by which means the object becomes more illuminated

than in the refracting telescope, and will suffer a greater magnifying power, without producing indistinctness from the dispersion of light. In this respect the *Newtonian reflector* possesses greater advantages than the Gregorian, as the larger speculum loses no part of its surface by perforation.



Let A B C D be a large tube open at the end C D and closed at A B; the length B D being at least equal to the focus of the metallic reflector F E, which is placed near the end of the tube. The rays G g I i, which come from H, a distant object, being considered as parallel to each other, fall on the concave speculum E F, and are reflected back upon a small speculum at L. This being inclined in an angle of forty-five degrees, the rays are reflected from its surface and carried to N, a convex lens fixed in the side of the tube, where the image appears magnified and distinct to the eye. By fixing a small tube with lenses to the side of the telescope at N, the image is further increased and brought into an upright position.

The Gregorian is more generally employed

than the Newtonian telescope, on account of its more convenient adjustment, the eye being brought into the same line with the object. When the Newtonian telescope is employed, the observer looks in at the side of the instrument, or at right angles to the tube and the object.

The present improved state of astronomical reflecting telescopes, which we owe to Dr. Herschel, varies in some measure from both the preceding.

The large instrument that this laborious astronomer has made, is formed of a tube about forty feet in length, and upwards of four feet in diameter. It is open at one end, and at the other extremity is a large concave speculum of nearly the same diameter as the tube, which converges the image of celestial objects into magnifying lenses, placed on the lower side near the open end.

When the instrument is employed, the open part is directed towards the object, and the reflected image is seen by the observer, as he sits in a chair, suspended from the upper end of the telescope, with his back to the object, and his eye near the lower edge of the tube.

From the great quantity of light that is obtained by means of the large speculum, the object is capable of being magnified six thousand times; but this prodigious power can rarely be employed, for the medium is magnified as well as the object; and it seldom happens that the atmosphere is in

a state to admit of the power of the instrument: so that the best and most valuable observations of Dr. Herschel have been made with an eighteen feet reflector.

Microscopes are optical instruments, which are employed for examining those minute parts of nature that are perfectly invisible to the unaided eye.

The exquisite picture of another creation which the microscope opens to our view, excites our wonder and admiration; and whilst we are instructed in the minuter operation of the animal, vegetable, and mineral creation, we are captivated with the admirable construction and sublime order which reign throughout the whole.

Small objects require great intensity of light to render the parts visible: it is on this account that the *solar microscope* far exceeds any other for the purpose of minute investigation.

This instrument consists of a tube about nine inches long, and about two inches and a half in diameter. At the wider end is a double convex lens, which converges the direct rays of the sun upon minute objects, at the opposite extremity of the tube, and a magnified image is produced by highly convex lenses, upon a white medium, at a few feet distance.

When this instrument is employed, the room is darkened, and it is fixed in a circular hole in the window-shutter: a small mirror placed

outwards, which may be moved in any direction, serves to reflect the solar rays upon the large convex lens at the end. With an instrument of this kind an object only a quarter of an inch long may be magnified with sufficient distinctness to the extent of six or seven feet.

Microscopes are also formed by single and double lenses, on optical principles that have already been explained. These produce a very striking effect; and, although they are inferior to the solar microscope in magnifying power, they may be employed at any time, and in any situation, which is not the case with the solar microscope, as it is quite useless without direct rays from the sun.

Vision. The eye is an organ of communication that exhibits an arrangement of various substances so correctly and delicately adapted to the purposes of the sense of vision, that we cannot help admiring at every step the wisdom by which each part is adjusted to the rest, and made to conspire in effects so different from what might be expected from external appearances; but the most laborious investigation has not been able fully to develope the nature and operation of this wonderful structure: there are powers of arrangement which are very ill explained; even the use of some of its parts is not understood, and the means of communication between this organ and the mind, is a difficulty which we cannot hope to surmount.

The eye-ball which is placed in its bony orbit, is nearly spherical, and is composed of transparent substances of various refractive densities. This is calculated to collect the rays of light that diverge from each point of an object to a focus on its posterior surface, and from whence the impressions are transmitted to the mind.

The first refraction takes place at the surface of the *cornea,* or that transparent coat which projects forwards from the ball of the eye ; but the cornea being of equal thickness, it has no effect by its own refractive power, and serves only to give a proper form to the aqueous humour which fills its concavity and distends it. This humour is partially divided by the *uvea* or *iris,* which is of different colours in different persons, having a perforation in its centre, called the *pupil.*

Immediately behind the uvea, and closely connected to its base, are the *ciliary processes,* the summits of which hang like a short fringe before the *chrystalline lens ;* a substance much more refractive than the aqueous humour, and increasing in density towards its centre. The remaining cavity is filled by a beautiful transparent substance, called the *vitreous humour.*

The *retina* lines, the whole posterior part of this cavity, it is semi-transparent, and is supported by the *choroid coat,* which is a very opaque black membrane in man, and of different colours

in other animals, that is continued from the uvea and ciliary processes. But immediately where the retina is connected with the optic nerve, the choroid is necessarily perforated, and at this part a small portion of the retina is insensible. The whole of the eye is surrounded by an opaque continuation of the cornea, called the *sclerotica.*

The rays of light which enter the cornea and pass through the pupil, are rendered still more convergent by the chrystalline lens, and are collected into foci on the retina, and there form a distinct image.

When the attention is not directed to any particular object of sight, the refractive powers of the eye are adapted to the formation of images, at a certain distance only, which is different in different individuals. For instance, if we open our eye-lids suddenly, without any particular preparation, we find that distant objects only appear as distinct as we are able to make them. By an exertion of the will, the eye may be accommodated to the distinct perception of nearer objects; but these must not come within certain limits: a person possessing the powers of distinct vision, is notable to see an object clearly at a less distance than about eight inches from the eye.

Between the ages of forty and fifty the refracting powers of the eye usually begin to diminish; and after fifty or sixty, the power of changing the focus is always much impaired, and sometimes wholly lost.

It has already been explained that the focal distance of a glass lens depends upon the distance of the object that is before it, and that the focal distance varies with the different distances of the object; yet the eye possesses adapting powers which bring the focal points of the object upon the retina at all distances.

There have been very different opinions to explain the means that nature employs to effect this operation. As the distance from the chrystalline lens to the retina always remains the same, it cannot be presumed that the focal adaptation can arise out of any variation of distance between the chrystalline lens and the retina. It was formerly supposed to be produced by a change of convexity in the cornea; some now imagine that the chrystalline lens varies its convexity according to the distance of the object, by means of the muscular action of the ciliary ligament, and processes that surround it.

The muscular construction of the iris enlarges and diminishes the pupil, admitting more or less light into the eye according to its intensity; consequently the pupil is diminished during the day, and involuntarily expanded in the night, when we have greater necessity for light to distinguish objects.

The iris is also peculiarly useful in excluding such parts of lateral pencils of light as fall very obliquely on the cornea, and would not be

regularly refracted; whilst those that fall more directly are admitted.

Distinct and *indistinct vision*, when disease is not concerned, generally arises from the different convexities of the cornea.

If the *cornea* has its *due degree of convexity*, the rays which carry the impression of the object are so converged that the foci fall upon the retina and produce a distinct image.

When the *cornea* has *too great convexity*, it renders the converging rays from the object too convergent, and the distinct image forms in the vitreous humour, before it arrives at the retina.

An eye of this description, in obtaining distinct vision, brings the object very near to it, that the image may recede, until it falls upon the retina. Or a concave lens is used, which renders the converging rays from the object less convergent; consequently throws the focal point further back upon the retina.

Between forty and fifty years of age the aqueous humour begins to diminish, which *lessens* the *convexity* of the cornea; so that we are obliged to have recourse to optical aid.

In this state of the eye the flattened cornea does not sufficiently converge the rays of light which it receives from the object; consequently the focal point is produced beyond the retina; and to obtain distinct vision, or to bring the focal point into its due situation, the object is held at

a greater distance from the eye. Or a convex lens is employed, which renders converging rays more convergent, and diminishes the focal distance that has been produced by the natural lenses of the eye, and this brings the image upon the retina.

When impressions of the same object fall on certain corresponding points of the retina, in each eye, they appear to the sense only as one; but if they fall on parts that are not correspondent, the object appears double.

The optical axis of the eye is an imaginary line passing through its centre to the retina, and takes different directions according to the action of the external muscles. When an object is at a great distance from the observer, the optical axes are nearly parallel to each other, but form an increasing angle, as the eyes are directed to nearer and nearer objects.

These different angles are of considerable importance in bringing us acquainted with the distances of objects, when they are joined with the visual angles; for we estimate distance much less accurately with one eye than with both, being deprived of the assistance which is afforded by the relative situation of the optical axes; so that a person seldom succeeds at the first trial in attempting to pass his finger through a ring presented sideways, with one eye shut.

We likewise assist our judgment with respect

to the magnitude and distance of objects, by the different degrees of distinctness, which they possess, at different distances, through the interposed medium of the atmosphere. In a mist or fog, the obscurity increases the apparent distance, and, consequently, the supposed magnitude of the unknown object.

We insensibly observe, in estimating distance, the number and extent of the intervening objects; so that a distant building in a woody and hilly country, appears more remote than if it were situated in a plain; for a similar reason, the apparent distance of a ship at sea is always less than its true distance.

When we have no means of estimating relative distance, we are guided by the visual sense alone, and then every object appears equally remote. For instance, if a number of lighted candles be placed at various distances, in a dark night, they all appear at the same distance, arranged in the arc of a circle, with the eye of the observer placed in the centre.

On the same principle all celestial bodies, both stars and planets, appear dispersed through the heavens in a concave semisphere.

In both cases we are shut out from comparing distance. In the first, from total darkness; and in the second, from the inconceivable extent even of the nearest of the celestial bodies; so that we are left to our visual sense, which impresses the mind with magnitude only.

When blind persons obtain sight they invariably complain of the great confusion which they experience from surrounding objects. Every thing seems to them at the same distance, for they are unable to compare and deduce; or, to make use of the emphatical language of one of these sufferers, "they have to learn to see."

We have from the earliest period of our existence, an involuntary and insensible habit of comparing the distances of different objects, so that by involving them in their visible appearance we become acquainted with their actual magnitude; but those who have just obtained sight, want this experience, and can only judge of objects by their visual angle; but the general principle soon begins to operate; they obtain ideas of relative distance, and the mind is impressed with the relative position of objects.

ASTRONOMY.

THE finger of the Creator is impressed on all his works; and every part manifests his infinite wisdom and design.

Our views have hitherto been directed to an examination of the laws of nature, which are constantly operating upon the surface of the earth; but the subject of astronomy leads us far from this terrestrial abode, it enables us to penetrate the regions of infinite space, to develope the majesty of creation, and observe the power of God made manifest in the greatness and fullness of his works.

The visible heavens are composed of three different orders of bodies, *stars*, *planets*, and *comets*.

Planets and comets are opaque masses, which are rendered visible by the reflection of solar light from their surfaces; and with the sun, constitute what is termed our system.

There are eleven primary planets or earths that revolve round the sun, and eighteen secondary bodies or moons that revolve round their

respective primaries, whilst they are performing their annual revolutions. The cometary bodies revolve round the sun in periodic times, and compose a part of our system; but we are still unacquainted with their number, time, and destination.

The *stars* are infinitely more numerous than the planets, and afford the most sublime views of their divine architect. What mind can contemplate with indifference, those brilliant orbs that are scattered through the apparently concave sphere of the heavens:—he cannot think, like the earlier astronomers, that they were intended as a mere ornament to this earth, and to give a feeble light in the absence of the sun. The human mind, strengthened and enlarged by the present enlightened æra of science, must believe that the stars are formed for much more noble purposes, in the grand scheme of creation.

In a clear night we can discern above a thousand stars with the naked eye; they appear of different magnitudes, or of various degrees of brightness, and seem to be placed at the same distance from us. We are perfectly aware, on the plainest optical principles, that this apparently concave hemisphere which surrounds us, is an optical illusion. We feel firmly convinced that the stars are disseminated throughout the heavens to an infinite extent; and that the different

degrees of brightness which they possess is the consequence of their different distances.

The stars are classed by astronomers according to their visible magnitude: those that are the brightest are of the first order, and supposed to be nearest to us: the next in brilliancy are called of the second maguitude, and so on to the sixth; which includes all the stars that are visible to the unassisted eye: the next are called telescopic stars.

The distance even of the nearest stars is so immensely great, as to defy the power of computation. Syrius, for instance, is a star of the first magnitude, and supposed to be nearer to us than any other. If this star be viewed by the most powerful telescope in those two situations of the earth, which are the nearest and most remote from it, and which differ from each other by the whole diameter of the earth's orbit, we do not find the least sensible difference in the appearance of the star; nor a variation of two seconds, in the angle which it subtends with the plane of the earth's orbit; although the observer has advanced one hundred and ninety millions of miles nearer to it.

Even light, which travels with a velocity of two hundred thousand miles in a second of time, would take up more than twenty years in passing from Syrius to the earth: and yet we see a thousand stars dispersed through the heavens that are still more remote than Syrius, and

probably placed at as great distances from each other as we are from them.

This mass of created matter, which glorifies the power of the Deity, and confounds the finite perceptions of man, constitutes but a point; it is only the commencement of his works. The telescope has opened an infinite creation to our view. Soon after it was discovered, our countryman, Flamstead, the first astronomer royal, furnished us with a catalogue of more than three thousand stars that had never been seen by human eye; and this number has been continually augmenting according to the improvement of the instrument; so that we are now in actual possession of catalogues containing the places of thirty thousand stars; so regularly classed and numbered, that if one were exterminated or another created, it would be observed by the practical astronomer; and yet, if the whole of these were wiped away from the face of the heavens, to that eye that could take in the whole extent of creation, they would be no more missed than a pebble from the shore. Herschel tells us, that when he turned his powerful telescope to that part of the heavens which is called the milky-way, he observed above a hundred thousand stars in a quarter of an hour; and wherever he directed the instrument in this illuminated belt, myriads of stars constantly presented themselves to his astonished view.

We naturally ask, What are these newly-discovered bodies? For what great end are they intended?

The first question may be answered, by direct inference: the second, by analogy.

We are certain that these stars are original sources of light, and that they are not like our earth, or the other planetary bodies, only visible by reflection: for if the stars were opaque spherical bodies, they could never be seen, from the great divergency of the reflected rays, at such immense distances. They must therefore be original sources of light like our sun, and many of them of much greater magnitude: for it has been calculated, by comparing the intensity of the sun's light with that of Syrius, that if the sun were as far removed from us as this star, instead of the first magnitude, it would appear like a star of the fourth.

We are truly sensible that one of the primary objects of the sun's creation, is to be a neverfailing source of light and heat to the surrounding planets, that his vivifying influence may bring forth the fruits of the earth in due season, and supply the temporal necessities of man. Another important point depends on the superior quantity of matter that composes the mass of the sun; this becomes a central and bounding influence to the earth and all the rest of the planetary bodies;

which restrains them in their respective orbits whilst they circle round him.

When we survey the opaque spheres that compose our system, and observe such a strict correspondence, in every visible appearance, between them and our earth, we are led to conclude that they must be intended for the same important purposes;—that is, to be an abode for man in a probationary state of being, that he may purify and perfect himself for an eternal existence in the presence of his Creator.

When we reflect on the multitude of rational souls that cover this earth, and conceive that all the surrounding spheres which revolve in our planetary region are equally peopled with myriads of inhabitants, we are lost in wonder and amazement. But what is this, in the scale of creation!—If we judge by analogy, and suppose that those myriads of stars which we view, are suns like our own, with a certain number of habitable worlds revolving round each of them, populated like our earth with living and eternal souls, praising God and seeking the intercession of Christ to save them from the fallen state of their own nature, that they may rise to eternal glory, through the mercy of the Father.

How weak is human language to express these wondrous works!—This blaze of infinite power overwhelms the feeble influence of the mind, and

we are lost in silent adoration of the stupendous prospect which it has created.

These are the objects of true philosophy; the advantages of well-directed science, that embraces the temporal and eternal interests of man, and rescues itself from the foul calumny of bigotted enthusiasts. It is true that the word philosophy has been made the stalking-horse of atheism; but the principles of the Mirabeaus and the Condorcets are happily laid in the same grave with their professors. The progress of true science suffers man to enjoy the dignity of his nature, free from the mischievous principles of infidelity, or the fetters of wretched bigotry and fanaticism which have formerly obscured it; and may this and every future age have to boast of christian philosophers, like Boyle, Bacon, Locke, Milton, and Newton.

Laws of planetary motion. The first object that presents itself in a general view of the phænomena of our system, is an illustration of the laws of planetary revolution: these are founded upon those principles of attraction and repulsion, which have already been explained.

Let us suppose the earth just aggregated from its chaotic state, through the influence of attraction, and impressed with motion in a rectilinear direction; if no other influence operated, the body would pass on for ever in this course; but if we suppose the attraction of the sun to act upon the earth, at the same time that it receives

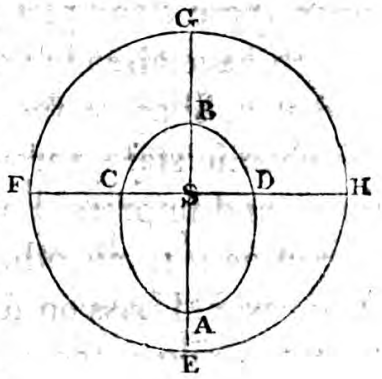
its projectile force, it will take a direction compounded of these two powers; and if they be perfectly equal to each other, will revolve round the sun, or central influence in a circular orbit; but if these forces are unequal, the orbit of the revolving body will be an eclipse, with an eccentricity, or difference between the major and minor axis, according to the difference of the forces.

The earth revolves in an elliptical orbit, and the larger is to the smaller axis as one hundred to ninety-nine.

When a planet revolves in an orbit perfectly circular, it passes through equal spaces in equal times: that is, whatever distance it passes through in a day or a week, it will pass through an equal distance in another day or another week.

If the earth revolve in an elliptical orbit, the influence of the sun's attraction is constantly varying, as the distance of the earth from the sun; and the velocity of the earth, in its orbit, will likewise vary accordingly; but the planet still describes equal areas in equal times.

Suppose C the earth, and S the sun in one of the foci of its orbit, the line C S may be considered as moving on with the earth, and in any given period a certain area will be included within these lines



and that portion of the earth's orbit which has been described during the period. If this area be represented by the triangle C S B, the similar area B S D will be described in equal times.

From the elliptical orbit in which the earth revolves, the summer division is greater by nearly eight days than that of the winter. That is, the orbit C A D, or from the vernal to the autumnal equinox, is seven days, seventeen hours, and fifty-three minutes more than D B C, or from the autumnal to the vernal equinox.

The apparent diameter of the sun is greater in winter than in summer. For the earth is nearer to him whilst it is passing through the winter signs D B C, than in passing through the summer signs C A D.

It might naturally be asked, why the winter is colder than summer, as the sun is nearer the earth?

This arises from the inclined axis of the earth, which gives the sun a greater altitude at mid-day in summer than in winter; consequently, the quantity of light and heat evolved is greater at this period than when the sun has less altitude. The day being longer in summer than in winter, also suffers a gradual accumulation of heat, which makes it generally hotter after the sun has passed the summer solstice than in the preceding month.

The earth. In early ages the opinions of mankind were very much divided respecting the form of the earth. Some being guided by sensible

appearances, conceived it to be a stationary plane, bounded by the horizon, and that the whole universe was contained in that part of the heavens which was exposed to their view.

At the present period we are well aware that the earth is a *spherical* body, aggregated from its chaotic state by the influence of attraction. As a popular and direct proof, we find that circumnavigators have set out from a given place, and by sailing continually in an easterly or westerly direction, have arrived again at the same place from whence they set out.

If we stand on the shore and observe a vessel making out for sea, the hull disappears first, then the sails, and lastly, the top-mast-head: this effect can only be accounted for by supposing the surface of the earth to be convex.

Ships sailing northwards observe an increasing elevation of the polar star; and those that sail southwards observe its depression, until it sinks beneath the horizon. These effects can only arise out of the rotundity of the earth: if its surface were an extended plane, the star would constantly preserve the same height in every situation.

Eclipses of the moon are caused by the earth's shadow falling upon that luminary. Partial lunar eclipses have always a circular edge, which can only be explained by supposing the earth globular.

The irregularities, or mountains on the surface of the earth, cannot have any visible effect upon

its shadow on the surface of the moon; when we consider that the distance of the moon from the earth is two hundred and forty thousand miles, that the diameter of the earth is nearly eight thousand, and the highest mountain on its surface not more than four miles.

The centrifugal force of the earth, which is produced by its rotation on its axis, flattens it towards its poles, so that an equatorial diameter exceeds a polar diameter of the earth by thirty-four miles; but this small deviation from a perfect sphere cannot make any variation in the circular edge of its shadow when it is projected upon the surface of the moon.

Those who consider parts instead of wholes, have some difficulty in conceiving how a sphere may be inhabited on every side; or how we can exist upon the surface of the earth with our feet directed towards each other; or that persons can walk on the under side whilst we walk upon the upper.

The terms upper and under can have no existence with respect to the earth itself: let imagination emanate in infinite radii from the earth's centre, the lines are equally interminable; so that the finite perceptions of man are immediately lost in the infinite extent of the universe. Yet if a ball be held near the surface of the earth, it has its upper and its underside; and if a body be placed upon it, unless the centre of gravity be

supported, it will fall by the influence of attraction; but the earth has no such relation with respect to any other body, and the power of attraction operates equally on every part of its convex surface. The sight is bounded by a small circle, which is called the visible horizon, with the eye of the observer in the centre; as we move, this circle moves with us; so that we are always upon the most elevated part of that space which our vision embraces; and thus it is that we conceive ourselves upon the uppermost part of the earth's surface.

The earth has two general motions, one round its axis in twenty-four hours, which is called its *diurnal rotation:* the other round the sun, which constitutes its *annual motion.*

By the *diurnal rotation* of the earth, the same phænomena occur as if all the celestial bodies revolved round it, so that in its motion from west to east, when the sun or a star appears just on the eastern side, it is said to be rising; and as the earth continues its revolution, it seems gradually to ascend, till it has reached the meridian, which is directly south of the observer: here the object has its greatest altitude, and it then begins to decline, till it sets or becomes invisible on the western side.

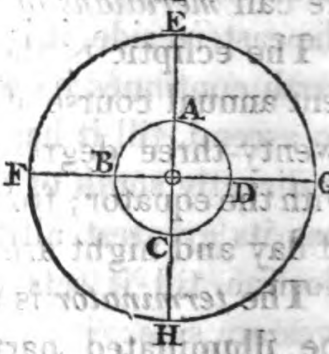
All the heavenly bodies do not appear to rise and set: those that are placed in the two poles, or are opposite to the earth's imaginary axis,

have no apparent motion from its diurnal rotation; therefore always appear stationary, or in the same points of the heavens.

The atmosphere that surrounds the earth reflects the sun's light, and supplies us with these rays for some time after we are shut out from the direct light, by the convexity of the earth's surface: this is called *twilight;* it takes place before sun-rise and after sun-set: it not only prolongs the natural day, but gradually prepares the organ of sight, for the increasing or diminishing influence of the direct rays from the sun.

To the visual sense, it seems that the earth is fixed in the centre of a concave sphere, and that the sun and the rest of the celestial bodies have a daily motion round it.

The same effects are produced whether we suppose the sun or earth in motion; that is, either of them would apparently describe a great circle in the heavens, in the plane of the ecliptic.



For if we suppose the earth to be at rest, and the sun to revolve round it in the orbit **A B C D**, it would appear to an observer on the earth to describe the great circle **F E G H**, in the heavens. For if an observer on the earth at **O**, views the sun at **A**, it will be referred to **E**, and at **B** to **F**, and so on of the rest.

But if the sun be placed at O, and the earth in the orbit A B C D, when the earth is at A, the sun will appear in a great circle of the heavens at H: when it is at B, the sun will be seen at G, and so on with the other two points. Therefore, whatever regards the sun's place with respect to its appearance in the heavens, it may be considered as moving in an infinitely great circle, called the ecliptic, having its centre in the eye of the observer.

The *different lengths* of *day* and *night*, and the change of *seasons*.

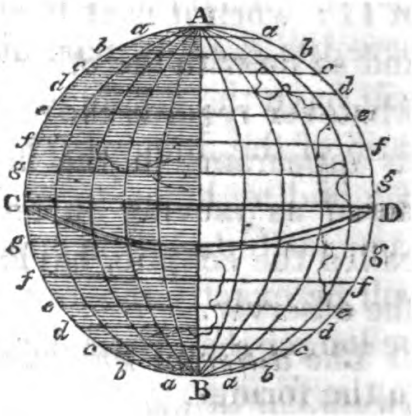
The earth is supposed to be divided into two equal parts, by a great circle drawn at equal distances from the two poles, which is called the equator. Smaller circles drawn parallel to it, and approaching the poles, are called *parallels of latitude*: great circles intersecting the equator at right angles, and passing through the poles, are call *meridians of longitude*.

The ecliptic is the earth's orbit, or the apparent annual course of the sun, making an angle of twenty-three degrees and twenty-eight minutes with the equator; from which the different lengths of day and night are derived.

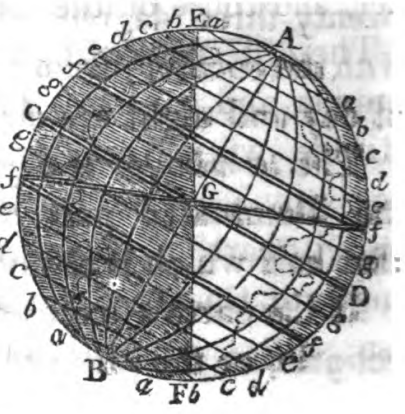
The *terminator* is a great circle which bounds the illuminated part of the earth's surface, or that half which is always turned towards the sun.

If the earth's axis were perpendicular to the ecliptic, or the plane of its orbit, the terminator

would constantly pass through the two poles, during the whole of its annual revolution, and divide every parallel of latitude into two equal parts.



Let A B C D represent the earth, with its poles A B, so placed that the terminator of the sun's rays may pass through each pole; then it will likewise divide every circle or parallel of latitude aa, bb, cc, &c. into two equal parts, so that one half will be enlightened by the sun's rays, and the other will be shut out; but during a diurnal rotation, every part of each circle will be successively brought to the terminator, and be carried through the illuminated part in the same time; which renders the days and nights of the same length on every part of the earth's surface, except at the poles A and B, where the sun would be constantly seen skimming just above the horizon.



But if the axis of the earth A B, does not coincide with the great circle of the terminator E F; the great circle C D, called the equator, will be divided into two equal parts at G, and the inhabitants under that line,

will have their days and nights of equal length; but the parallels a a, b b, c c, &c. will be divided into two unequal parts, by the terminator E F; and the inhabitants under those parallels which have the greatest part of their circle illuminated, will have the days longer than the nights in the ratio of the illumined, to the darkened part. The day and night of those persons who are in the same latitude, but on opposite sides of the equator, will be exactly the reverse; for their night will be longer than their day, in an inverse proportion to the former.

It is obvious from the inspection of the figure, that as the parallels increase from the equator, those places that lie under them will have a greater disproportion of day and night; so that those which are at or near the pole A, will have constant day, or the sun always above the horizon; and those at the opposite pole E, will have continual darkness, or the sun always below it.

In the present position of the axis, those on the northern side of the equator have their summer, and those on the southern, winter.

The difference of light is not the only cause of summer and winter. The sun has the greatest altitude when the days are the longest, consequently a greater number of rays fall on any limited part of the earth's surface: the great length of time that the sun is above the horizon, also suffers an accumulation of heat, which

generally renders it hotter after the summer solstice than before it.

Having thus shewn that the length of day and night entirely depends on the bisection of the parallels of latitude, by the different relations of the earth's axis to the terminator, the next object is to shew how the relation varies at different times of the year, by which means the different seasons are produced.

We find, by common observation, that the sun describes different parallels daily, or appears at different heights above the horizon; which shews that the plane of the ecliptic, or sun's apparent path, does not coincide with the plane of the equator; otherwise the sun would have constantly the same altitude, and days and nights would always be of the same length; we therefore conclude, that the axis of the earth is inclined to its orbit. It is found that this inclination of the planes of the equator and ecliptic, forms an angle of twenty-three degrees twenty-eight minutes; which remains invariable through the whole of the earth's annual course; and that the axis of the earth always moves parallel to itself.

Therefore, if the earth's axis be inclined to the plane of its orbit, or the ecliptic, as in the last figure, one of its poles will be towards the sun, and the other will be removed from it in an equal proportion; but when the earth has made half of its revolution, or has arrived in the opposite point

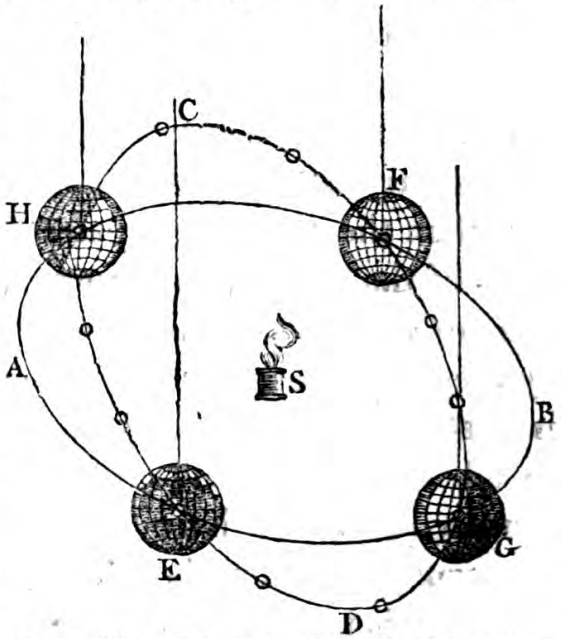
of its orbit, the pole which was towards the sun will now be removed from it, and the opposite pole which was darkened will now be illuminated.

As the earth passes from one of these extremes to the other, the plane of the ecliptic will coincide with the plane of the equator, near the intermediate distance, between the extreme points, and then the terminator passes through the two poles of the earth, as in figure the first.

The different seasons of the year are produced by these changes; for when the northern pole is most inclined towards the sun, it is midsummer to all the inhabitants on the north side of the equator, who then have their longest day, and consequently, their shortest night. But when the earth is in the opposite part of its orbit, or one hundred and eighty degrees distant, the southern pole has the greatest inclination, and the inhabitants on that side of the equator have their midsummer and longest day; whilst those in the northern hemisphere have their shortest day or midwinter.

When the earth is in the intermediate part, or about ninety degrees distant from either extreme; that is, when the plane of the ecliptic coincides with the plane of the equator, the day and night are of equal length all over the earth, which constitutes the vernal and autumnal equinoxes, or spring and autumn.

The following contrivance affords a very easy and familiar illustration of the different lengths of day and night, consequently of the seasons.



Let a narrow hoop, or strong wire C D, represent the elliptical orbit of the earth, which intersects the equator A B, in the two points or nodes E F, making an angle of twenty-three degrees and half, which is the inclination of the earth's axis to the ecliptic, and let S be a lighted candle, placed in the centre of the frame, representing the sun near the centre of the planetary system. The ecliptic C D, may be divided into twelve signs, and the corresponding months marked against them.

If a small globe, representing the earth, be suspended by a string from E, where the circles intersect each other, and the eye be placed near the light, in the centre, an illuminated hemisphere will be observed extending to the two poles. The earth is now in the sign of the Balance, and

the apparent situation of the sun in the heavens, at this time, will be in the sign of the Ram, or at F, on the opposite side of the ecliptic: this is the vernal equinox, which happens about the twentieth of March, or when the terminator passes through the poles of the earth, and makes the days and nights of equal length all over its surface.

Whilst the small globe is moving through the Balance, Scorpion and Archer, the terminator or edge of the light keeps increasing beyond the upper or north pole, until it has received its greatest degree of illumination in the Goat G. Now the sun is seen in the opposite part of the heavens, or in the Crab H, which happens on the twenty-first of June, and all the parallels of latitude, in the northern hemisphere, have the greatest portion of their circles illuminated; consequently the day is now the longest, and the night the shortest; but the duration of light, or the length of day, is in proportion to the distance of the parallels from the equator, the length of day gradually increasing from the equator to the north pole, and decreasing in like ratio from the equator to the south pole.

Whilst the globe passes towards F, through the Goat, Water-bearer, and Fishes, we shall observe the return of the terminator towards the north pole, until the globe reaches the Ram, then both poles will be illuminated; the apparent place of the sun will be in the Balance E, and the

days and nights will again be of equal length all over the earth. This period is called the autumnal equinox, which happens about the twenty-second of September.

If we move on the globe through the Ram, Bull, and Twins, until it reaches H, the first degree of the Crab, the terminator shuts up the northern pole in darkness, and enlightens the regions about the southern. Now the sun enters the opposite sign G, the Goat, which is about the twenty-first of December, and the greater part of the circles or parallels of latitude in the northern hemisphere are in darkness, whilst those in the southern have their greatest portion of light, which produces mid-winter in the northern and mid-summer in the southern hemisphere.

As the globe is taken from H to E, through the Crab, Lion, and Virgin, the terminator will be seen advancing towards the poles, until it regains its first position in the Balance, and completes its annual revolution.

The earth, independently of its diurnal and annual revolution, has another small motion, which produces what is termed the *recession* of the *equinoxes*.

When the sun sets out, from the moment of the vernal equinox, in its apparent annual course through the ecliptic, it will return again to this point in the heavens, in three hundred and sixty-five days, five hours, and forty-eight minutes:

but if the sun should chance to be in conjunction with a star, at the instant of the vernal equinox, it will take up three hundred and sixty-five days, six hours, and ten minutes, before it will return to the star again; making a difference in time of abuot twenty-two minutes; or fifty seconds, in parts of a degree, annually.

The first period is called a solar, and the second a sideral year; and the annual difference constitutes what is termed the recession of the equinoxes.

Newton inferred from the general laws of gravity, that this small variation between a solar and a sideral year, was produced by the compound influence of the sun and moon upon the protuberant matter accumulated about the equitorial part of the earth's surface, by the rotation of the earth upon its axis.

Chiron, who existed a few years before the memorable seige of Troy, has the reputation of having divided the heavens into constellations. Hipparchus divided the ecliptic into the twelve signs of the zodiac, which at that period coincided with the twelve constellations; but on account of the recession of the equinoxes, the present situation of the signs vary from the constellations upwards of thirty degrees; so that the sign of the Bull is in the constellation of the Ram.

The Moon is one of those bodies called satellites: it is a secondary to the earth, and revolves round

it; or rather, the earth and moon revolve round a common centre of gravity, which describes what is called the earth's orbit.

The moon's apparent place viewed by a spectator upon the earth, is extended to a great circle of the heavens, and appears to move through the twelve signs of the zodiac, in a month or lunar day.

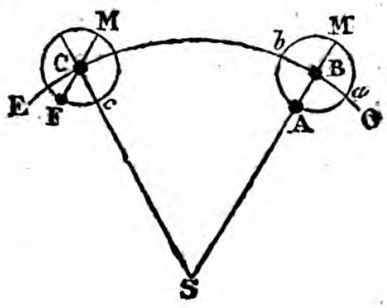
The plane of the moon's orbit, if it were extended, would intersect the ecliptic in two points, making an angle with it of about five degrees; these are called the nodes; and when the moon ascends from the south to the north side of the ecliptic, it is said to be in its ascending node; and from the north to the south, in the descending node. The line of the nodes is not always directed to the same point, but has a motion contrary to the order of the signs; and by this retrograde course it completes its circuit in eighteen years, two hundred and twenty-five days, at which time the line of the nodes returns to the same point in the ecliptic.

It is only when the moon crosses the ecliptic that it is in its nodes; in all other parts of its orbit it is said to be in north or south latitude, according as it is above or below the ecliptic.

The mean time of a revolution of the moon about the earth, that is, from one new moon to another, is called a synodical month, or lunation, and consists of twenty-nine days, twelve hours,

and forty-four minutes. The time of its revolution round the earth, from any point in the zodiac, to the same point again, is called a periodical month, and contains twenty-seven days, seven hours, and forty-three minutes. The moon moves in its orbit about two thousand, two hundred, and ninety miles in an hour, and only turns once round its own axis, whilst it makes a revolution round the earth, which causes it always to present the same side towards us, and makes its day and night of the same length as our lunar month.

If the earth were stationary, the periodical and synodical months would be the same; but as the earth keeps moving forwards in its orbit, whilst the moon is performing its revolution, it has not only to pass through its own orbit, but has likewise to overtake the earth again in its passage through the ecliptic.



For if S be the sun in the centre of the system, E O, part of the earth's orbit, and M A the orbit of the moon; when the moon is in conjunction at A, if the earth remained at B, whilst it made its revolution, A a M b A the periodical and synodical months would be the same; but during this revolution the earth has advanced in its orbit to C; therefore the moon must pass on to c before it can come again in

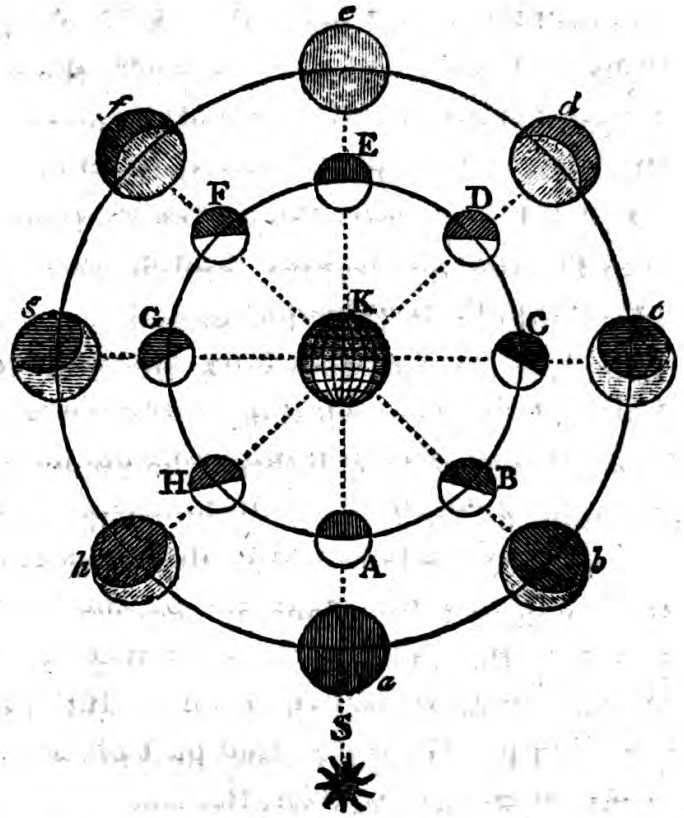
conjunction with the earth; but it is obvious, by inspection, that when the moon has arrived at F, it will have completed its revolution round its orbit; and the time of performing the remaining arc F c, will be the difference of time between the periodical and synodical month, which is about two days and five hours.

The moon is a dark opaque body, moving round the earth in a small orbit, and shines by a borrowed light from the sun, which illuminates one half of its body, and leaves the other in darkness. We perceive different degrees of this illumination according to the various positions of the moon, with respect to the sun and earth; hence we see one half of its body enlightened, or a full face, when it is in opposition, or in that part of its orbit which is the most remote from the sun.

When the moon is in conjunction, or between the earth and sun, its enlightened face is turned from us, which renders it invisible: this is the time of the new moon.

When the moon appears in the intermediate part of its orbit, between the conjunction and opposition, it is said to be in its quadratures, and about half of its illuminated surface is towards us.

Let S represent the sun, K the earth, A B C D, &c. the moon in its orbit, with the sun's rays falling on that half of its surface which is opposite to the sun, and the outer circle a b c d, &c. the various phases of the moon, as they appear to



a spectator on the earth during the whole of a lunar month.

When the moon is in conjunction with the sun at A, the darkened side is presented towards the earth; therefore, being an opaque body, it becomes invisible, and it is then called the time of new moon. When it has passed an eighth of its orbit, and arrived at B, a quarter of its enlightened surface is turned towards the earth, and it appears horned at b. In passing another eighth of its orbit, it arrives at C; it is then called in its quadrature, and one half of its surface appears illuminated at c: after having passed on to D,

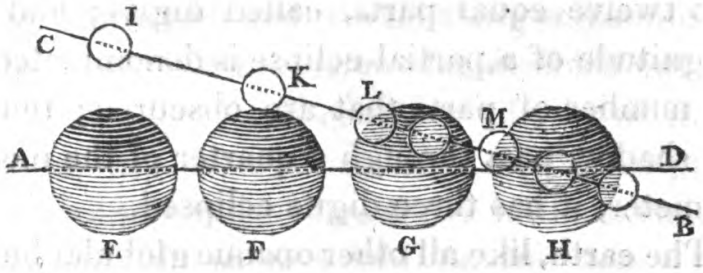
it appear gibbous, and more than half of its face is enlightened, as appears at d: at E, the whole face is seen bright, which is called the opposition, or full moon. It now begins to decline from E to F, and appears gibbous at f; thence it passes to G, the quadrature, and is seen at g, half illuminated; it then becomes horned at h, and falls into conjunction with the sun at A, which completes its revolution.

The earth serves to enlighten the moon in the same manner as the moon enlightens us; but its appearance is much larger than that of the moon, and the changes take place in contrary order; that is, when the moon appears full to us, the earth is in conjunction with the sun, which turns the darkened face to the moon, and must render it invisible. Soon after new moon, the whole body is dimly seen, independently of the illuminated crescent on its outer surface; this is occasioned by the light that is reflected upon it from the earth; for at the time of new moon, the earth must appear as a full moon upon the lunar surface, and part of its light is supposed to be reflected back again.

An *eclipse* of the *moon* is a privation of light, caused by the interposition of the earth directly between the sun and the moon, which intercepts the sun's rays, and prevents them from illuminating her surface. Or it may be considered as proceeding from the conical shadow of the earth

when the moon enters between the base and the vertex.

As the earth's orbit is in the plane of the ecliptic when it is viewed from the sun, it is evident that the earth's shadow must tend directly to that part of the heavens; and as the moon's orbit has an inclination of about five degrees with the ecliptic, and only crosses it in two points, called its nodes, the shadow of the earth cannot fall upon the moon, except it is in or near one of its nodes.



Let the line A D represent a part of the ecliptic, the plane of which coincides with that of the earth's orbit, and C B part of the orbit of the moon crossing the ecliptic at H, which is called its node. Then if E F G H represent the earth, or its shadow, in four different positions in its orbit; when the moon I approaches its node H, and the shadow of the earth is at E, it has no part of the sun's rays intercepted; but if the earth be at F, and the moon at K, a small obscuration takes place, and the moon is partially eclipsed. When the moon is at L, and the shadow at G, it enters wholly into it, which is

called a total eclipse; but when the moon's centre passes through the centre of the earth's shadow, as at H, which can only happen when the moon is directly in one of its nodes, it is called a total and central eclipse.

The duration of a central eclipse, or the time that the moon takes from entering the shadow to quitting it, is about four hours; during two hours of this time the moon passes through three times the length of its diameter totally eclipsed.

The moon's diameter is supposed to be divided into twelve equal parts, called digits; and the magnitude of a partial eclipse is denominated by the number of parts that are obscured; thus, if the shadow pass through a quarter of the moon's diameter, it has three digits eclipsed.

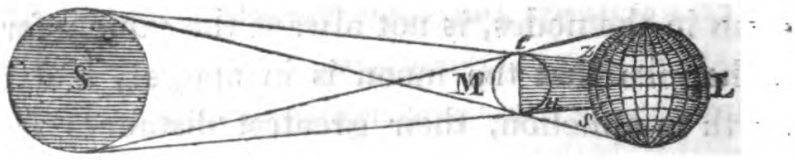
The earth, like all other opaque globular bodies which receive the sun's rays, not only throws a dark converging shadow behind it, but has likewise a thin diverging shadow on each of its sides, called the penumbra, which is occasioned by a partial obscuration of the sun's light.

Lunar eclipses are visible over every part of the earth that has the moon at that time above the horizon; and the eclipse appears of the same magnitude to all from the beginning to the end. Central eclipses are of the longest duration. As the moon quits its nodes, either into north or south latitude, the eclipses become more partial and of less duration. The length of an eclipse,

even in the nodes, is not always the same; for if it happen that the moon is in apogee, and the earth in aphelion, their greatest distances from each other, the length of the eclipse will be about three hours and fifty-seven minutes; but if it take place when the moon is in perigee, and the earth in perihelion, or their nearest distance, then the duration will be three hours and thirty-seven minutes only.

The moon's nodes have a motion from the consequent to the antecedent signs, which moves through nineteen and one third degrees annually; so that in eighteen years, two hundred and twenty-five days, it passes through all the signs in the ecliptic, and returns again to any given point. If the moon's nodes were fixed in the same part of the ecliptic, there would be just half a year between the times of the sun's conjunction with the nodes; therefore, in whatever sign or month of the year an eclipse should take place, it would always happen at the same time in every succeeding year; but as the moon changes the situation of its nodes in the ecliptic, for eighteen years, two hundred and twenty-five days, this time must elapse before the same eclipse falls in the same part of the ecliptic.

An *eclipse* of the *earth* is caused by the interposition of the moon between the sun and the earth, which can only happen when the moon is in or near the conjunction.



In an eclipse of the earth, let S represent the sun, E the earth, and M the moon in conjunction, or between the earth and the sun; then z s t u is the moon's conical shadow, which passes over z s, and produces an eclipse on a small part of the earth's surface. On each side of the conical shadow is the penumbra or thinner shade, which is caused by a partial privation of the sun's rays.

The moon being so much less than the earth, it can only cover a small part by its shadow; therefore, those who are out of its shade can observe no appearance of an eclipse. Even a central eclipse, that is, when the moon's centre passes through the diameter of the sun, can only be visible to those who have the moon above the horizon.

In eclipses of the earth the sun's shadow upon its surface does not in general exceed one hundred and eighty miles in diameter, though the penumbra extends many hundred miles round.

If the eclipse happen when the moon is exactly in its nodes, it will cast a circular shadow upon the earth; but when the moon has northing or southing, the shade is elliptical.

The whole time that the shadow and penumbra take up to pass any given point, is called the

general eclipse: the total eclipse is only whilst the darkest part passes the place. When the moon changes in its apogee or greatest distance from the earth, its shadow is not sufficiently long to reach its surface, and the sun appears like a luminous ring round the dark body of the moon, and forms what is called an annular eclipse: an effect of this kind will not happen until the year 1847.

Tides. Newton observing that high water returned again at the same time, after a period of twenty-nine days and twelve hours, was induced to conclude that the moon's influence was concerned in this effect, and agreeably to the general laws of gravity, which he had just discovered, he laid down his theory of tides.

If the earth were entirely covered with water; from the influence of attraction, the water would form a shell of uniform thickness on every part of its surface. Let us now suppose the moon to be placed stationary, in any point of its orbit; the influence of the moon's attraction upon the earth being according to the quantity of matter, diminishing in a certain ratio, according to the distance, that part of the water which is immediately under the moon, would be the most powerfully disturbed by the attractive influence. This would not only elevate the fluid immediately under it, but the water would likewise be attracted from the quadratures, or those two points, ninety

degrees distant, by which means there would be a depression of the water in those places, and an elevation at the same time under the moon.

When it is high water with those who have the moon above the horizon, it is likewise high water on the same meridian, on the opposite side of the earth, or one hundred and eighty degrees distant. This is supposed by Ferguson to be occasioned by a centrifugal tide, which arises from the revolution of the earth and moon round a common centre of gravity.

The centre of the earth, and moon's motion, is as much nearer to the earth as the quantity of matter contained in the earth exceeds that of the moon; or six thousand miles from the centre of the earth, and two hundred and thirty-four thousand from the moon.

The centrifugal force, or disposition that a body possesses to fly off, is according to the velocity; therefore, the greatest centrifugal force upon the surface of the earth will be at the greatest possible distance from the centre of motion, and this is constantly on the same meridian with the moon, but on the opposite side of the earth. It is this force which constantly elevates the water directly opposite to the greatest influence of attraction; and likewise tends to depress the fluid in the quadratures, and project it towards the meridian.

Thus, supposing the earth and moon to be

stationary bodies in the heavens, the globular shell of water by which we imagine it to be surrounded, would be converted by their attractive and repulsive forces into a permanent spheroid, having its longer axis constantly directed towards the moon; and during a diurnal rotation of the earth, an observer would have high and low water twice in twenty-four hours; for if we suppose him to set out from high water, or from the meridian under the moon, in six hours he is carried through ninety degrees, where he finds low water, produced by the united influence of the attractive and repulsive forces. From the quadrature he comes to the meridian on the opposite side of the earth, one hundred and eighty degrees distant from the moon; here he has high water, produced by the centrifugal force alone; from this situation the observer passes on to the second quadrature, and again finds low water: ninety degrees more brings him to high water at the same point from which he set out.

Let us now consider the earth and moon moving in their respective orbits: whilst the earth passes on in its annual course, the moon makes a complete revolution round the earth in the period of about twenty-nine days and twelve hours; she consequently describes an arc of the heavens, equal to about thirteen degrees daily; therefore, when an observer leaves the meridian of the moon; after a rotation of the earth on its axis, he falls

nearly thirteen degrees short of it; which must be passed over, before he arrives at his former position; this being converted into time, amounts to about fifty minutes. Hence, high water falls later by about three quarters of an hour daily; and in twenty-nine days, twelve hours, the time of high water returns again to the same period.

The influence of the moon alone has hitherto been considered in producing tides; but the sun would produce a small tide if the moon did not exist. This tide would be greatly inferior to that of the moon, although the attractive influence of the sun upon the earth generally, is much greater than that of the moon; but tides are produced by a partial, not a general influence.

The effects of the moon's attraction, from its proximity to the earth, is considerably greater on that side which is nearest to the moon than on the opposite side; but the attraction of the sun upon the earth is, on account of its great distance, nearly the same upon every part of its surface.

The disturbing force of the moon to that of the sun, is as four and half to one, or as nine to two. When the moon is on the same meridian with the sun, or at the time of new and full moon, the disturbing influences unite in elevating the water, in large and open oceans, which produces what are called *Spring Tides;* but when the moon is in the first and third quarters of her revolution, the disturbing forces oppose each other, and the

influence of the sun must be deducted from that of the moon, which produces what are termed *Neap Tides*. When no local causes operate, as in open seas, the spring tides are about eleven feet, and the neap tides seven feet.

Spring tides do not happen exactly at the time of new and full moon; nor high water when the moon is on the meridian; but some time afterwards, for the effect is not the greatest when the disturbing cause has the greatest influence; a maximum obtains, which is not till some time afterwards.

The time of high water in the Atlantic Ocean is not till two hours after the moon has passed the meridian. The wave or tide that is here produced, is divided by the Land's End, in Cornwall; one part going up the English, and the other up the Irish Channel, and the corresponding progress of these waves is thus traced.

At the Scilly Islands it is high water about two hours after the moon's southing; Plymouth, three; Cork, Bristol, and Weymouth, four; at Caen and Havre, in Normandy, six; Dublin and Brighton, seven; Boulogne and Liverpool, eight; Dover, nine; the Nore, eleven; and at London Bridge, twelve hours after the moon has passed the meridian.

Another portion of the primary tide passes round Ireland and Scotland, down the North Sea, and arrives at the Nore in about twenty-four

hours, where it meets the tide that has passed up the English Channel, in twelve hours.

The preceding observations may serve to give a general illustration of tides; but on every shore there are always a great variety of local circumstances operating, which produce an effect that varies greatly from the general principle. Thus, at Brest the height of the tide is sometimes twenty feet; at Bristol, thirty; Chepstow, forty; St. Maloes, fifty; and in the Bay of Fundy it is stated that the tide occasionally reaches the height of one hundred and twenty feet.

In small and narrow seas the tides are very inconsiderable: in the Mediterranean the tides are very small, but yet perceptible; at Naples it sometimes rises to the height of a foot; and at Venice to the height of two feet.

The extraordinary height to which the water rises at Chepstow, may be explained in the following manner:

The town of Chepstow is placed on the river Wye, about two miles above its confluence with the Severn: the Wye takes its rise amongst the mountains in Wales, and the torrents of rain which frequently descend in this district, suddenly elevate the river to the height of eight or ten feet. The Severn, three miles below Chepstow, is above three miles wide, and three miles above Chepstow, it is only a mile in width; so that the

tide which is forced up this channel from the Irish Sea, is greatly compressed between these narrowing shores, and is constantly thrown up to a considerable height, which makes the navigation of this river very dangerous at certain periods.

The extraordinary elevation of the water at Chepstow, is generally about the equinoxes, at the time of spring tides, when the waters of the Severn, aided by a strong wind, are driven up the mouth of the Wye, and meet the elevated torrent of the river descending in its rapid bed; the most direct opposition takes place near Chepstow Bridge, and here the water is sometimes elevated to the extraordinary height of forty feet and upwards.

There is a well in this town, sunk within two hundred yards of the river, which is not less singular than the tide. At the time of high water it is very nearly empty, and as the tide falls, the water rises until it obtains its greatest altitude, which is at the time of low water. This fluctuation is constantly taking place, and there is always the least quantity of water in the well at the time of spring tides, or when the altitude of the river is the greatest.

This may probably be accounted for, by supposing the fissure that supplies the well, to proceed under the bed of the river, from some elevated ground which is on the opposite shore; so that when it is high water, the weight of this extraor-

dinary column of fluid compresses the sides of the fissure, and stops the supply, whilst the water is constantly escaping from the divided aperture in the well; but as soon as a portion of the pressure is taken off from the bed of the river, the water in the fissure again begins to flow into the well, until it rises to its greatest height.

The *Solar System*, as far as is known, consists of the sun, eleven primary, and eighteen secondary bodies, or moons. The sun is the source of central influence, and preserves the planetary bodies in their respective orbits, whilst the whole revolve round the centre of gravity of the system, which is at the distance of about four hundred thousand miles from the surface of the sun.

This immense sphere is eight hundred and eighty thousand miles in diameter,—one million, four hundred thousand times bigger than our earth, and contains six hundred times more matter than all the planetary bodies of our system. If the earth be represented by a ball one inch in diameter, the sun would be represented by a sphere, upwards of twelve feet. It revolves on its own axis in twenty-five days, ten hours, and is inclined about seven degrees to the plane of the earth's orbit.

The spots which are occasionally observed on the surface of the sun, were noticed by Galileo, soon after the telescope was discovered. Herschel attributes them to the emission of an æriform

and highly elastic fluid, not in combustion, which displaces a portion of the shell of light that surrounds the sun, but speedily falls into a luminous state.

It was generally supposed by Newton, and others of that day, that the sun was a solid mass of combustible matter; by the decomposition of which, light and heat were evolved and projected through the system, to animate the surrounding orbs. It was even supposed that cometary bodies might occasionally fall into the sun, to supply the loss of inflammable matter. We can only reason from what we know, and "comparing great things with small," it is not extraordinary that at this early state of chemical science, they should come to these conclusions.

Our opinions respecting the sun, at the present time, are very different; if they are not nearer the truth, they, at least, afford a much more dignified view of this sublime subject.

It is supposed by Herschel, and some others, that the sun is a mass of solid matter, something like our earth, surrounded by an illuminating atmosphere; which, according to his calculation, commences at about two thousand miles from the surface of the sun, and forms a shell of about two thousand miles in thickness; and that underneath this shell there is a thick dense atmosphere, which surrounds the sun, and defends it from the effects of intense heat. He also supposes that the

opaque appearance in the central part of those spots that are occasionally visible on its surface, is a portion of the sun's proper atmosphere, which disappears as soon as the subtile fluid of the exterior shell is in a state to evolve light.

If this hypothesis has no very solid foundation in philosophy, it has however the more powerful sanction of revealed truth. "God said let there be light, and there was light."—At his almighty fiat, light was created; nature burst into existence, through the influence of its animating power, and its benignant rays still continue to shed innumerable blessings upon the temporary state of man.

Amongst the planetary bodies, *Mercury* is nearest to the sun. Its greatest elongation, observed from the earth, does not exceed twenty-eight degrees, which renders it rarely visible, as the reflected rays from the surface of this opaque body are lost in the more powerful influence of the direct rays from the sun.

The diameter of Mercury is more than three thousand miles; its distance from the sun thirty-seven millions; it takes about eighty-eight days to make a revolution in its orbit, and revolves on its own axis in twenty-four hours, five minutes.

Venus occasionally subtends an angle of forty-eight degrees with the sun, and on this account is seen much more conspicuously than Mercury. The distance of Venus from the sun is sixty-nine

millions of miles; it has a diameter of about seven thousand miles; revolves round the sun in two hundred and twenty-four days, and has a rotation on its own axis in about twenty-three hours.

Venus and Mercury are called *inferior planets*, because they revolve in their orbits at a less distance from the sun than the earth. It is on this account that these two planets appear to our visual sense, to describe a small arc in the heavens on each side of the sun, and to possess a progressive and retrograde motion. The greatest distance of Venus is forty-eight degrees, and of Mercury twenty-eight degrees.

When Venus and Mercury are in or near their superior and inferior conjunctions, or in the same line with the sun and earth, they are lost in the effulgent rays of solar light; consequently they are the most distinctly seen when they form the greatest angle with him.

When Venus is sufficiently removed from the sun, and is passing from her inferior to her superior conjunction, rays from the planet enter the horizon of the observer before the sun appears; in this situation Venus is called a *morning star*: but in passing from her superior to her inferior conjunction, the sun rises before the planet; in this case it is an *evening star*.

Venus, Mercury, and the rest of the planetary bodies, do not revolve in the same plane; their

orbits cross each other, and form different angles when compared with the plane of the earth's orbit: the inclination of Mercury is about six degrees, Venus four, Mars two, and some of the asteroids as much as twenty-eight degrees.

A line passing through the two points of intersection is called the *line of the nodes;* when this line coincides with the earth and sun at the time that the planet is in its inferior conjunction, it is seen passing over the sun's surface, like a small black spot, which is called a transit.

The transits of Mercury are much more frequent than those of Venus, on account of his quicker revolution; but the distinctness of the transits of Venus render them of much greater astronomical importance. The last transits of Venus were in 1761 and 1769: there will not be another until the year 1874.

According to an ingenious method laid down by Dr. Halley, the preceding transits of Venus were employed to determine what is called the sun's horizontal parallax, or the different places of the sun in the heavens, as it would appear to an observer at the centre of the earth, and another ninety degrees distant, on its surface.

From the extreme smallness of this angle, astronomers previous to Halley, could not agree upon the quantity; but according to the principles of this eminent philosopher, it is now admitted to be about eight seconds and a half, which

ascertains the distance of the earth from the sun to be ninety-five millions of miles.

Near two hundred years ago, Kepler discovered that there was a constant relation between the times and distances of the planets, which was "as the square of the time to the cube of the distance." That is, if one planet were four times as remote as another, the period of the latter would be eight times greater than the former, since the cube of four is equal to the square of eight. Mars, for instance, is nearly four times as remote from the sun as Mercury, therefore its time is eight times greater. Mercury takes about eighty-eight days, and Mars near two years to make a revolution round the sun. The Georgian is nearly four times as remote as Jupiter, and takes up about eight times as long to perform its circuit.

Although the general relation of the planetary times and distances were thus determined by this sublime law which Kepler discovered; yet the actual distances of the planets from the sun could not be correctly ascertained, until the true distance of the earth from the sun was determined by Halley's method.

To compute the actual distance of a planet from the sun, say,

As the square of the earth's time, or three hundred and sixty-five days,—Is to the cube of

the earth's distance from the sun, or ninety-five millions of miles,—So is the square of any other planet's time, (suppose Venus, two hundred and twenty-four days,)—To the cube root of the distance of Venus, or sixty-nine millions of miles.

The actual magnitude of a planet is deduced from its visible magnitude, compared with the visible magnitude of the earth at the same distance.

The sun, for instance, at a mean distance from the earth, subtends an angle of thirty-two minutes; but an observer in the sun would see the whole diameter of the earth under an angle equal to twice its horizontal parallax, or about seventeen seconds. Now, if we find the solidity of two spheres of seventeen seconds and thirty-two minutes diameter, the proportions will be, as one to one million, four hundred thousand; the relative magnitudes of the earth and sun.

The earth having been particularly considered in a preceding part, we will pass on to Mars, which is the next planet in the system.

This is the first of the superior planets, and is consequently seen both in conjunction and opposition; that is, an observer on the earth may have the sun and planet united, or have the sun on one hand and the planet on the other. In opposition, it is five times nearer than in conjunc-

tion, which has a very sensible effect upon its magnitude. Mars has a reddish hue, which is supposed to arise from the nature of his atmosphere. The diameter of Mars is about six thousand miles; the distance from the sun one hundred and forty-six millions; it revolves round its own axis in about twenty-four hours and half, and round the sun in rather less than two years.

Some of the continental philosophers have discovered between Mars and Jupiter, four very small planets which revolve round the sun. They are called *Ceres, Pallas, Juno,* and *Vesta,* and are supposed to be something less than the moon in diameter: the times of their revolution is from four to five years.

Jupiter is the largest of all the planets; it is one thousand five hundred times greater than the earth, and revolves round its axis in rather less than ten hours. It takes about twelve years to revolve round the sun, and is five hundred millions of miles distant from it. It has four satellites, each about the size of our moon, which revolve round it near the plane of its equator, in the different periods of one, three, seven, and sixteen days.

The axis of this immense mass is eleven times and a half greater than that of the earth, or upwards of ninety thousand miles; it is placed very nearly perpendicular to the plane of its orbit, so that the terminator constantly passes through the poles,

and the days and nights must constantly remain of the same length; that is about five hours each, independently of twilight. There are lines about Jupiter's equator, which are called his belts; these are supposed to be produced by the condensation of his atmosphere in these parts, from the immense velocity of the planet upon its axis. If an atmosphere be admitted, the twilight must necessarily lengthen the day, perhaps two hours; so that the night would be only three hours; and even during this period there is the advantage of reflected light from one or more of his moon's, so that no portion of the surface of this prodigious body can be considered in total darkness.

Saturn is the next planet in our system; about eighty thousand miles in diameter, and revolves in its orbit in twenty-nine years and half, at the distance of nine hundred millions of miles from the sun; a rotation on its axis is performed in about ten hours and half.

This planet is surrounded by seven attendant moons, which revolve in different periods from one to seventy-nine days. Five were discovered by Cassini, and two by Dr. Herschel.

The great singularity of Saturn consists in an immense ring, twenty-eight thousand miles broad, which surrounds it at the same distance from its surface.

There have been many opinions respecting the ring, but these are so opposite and improbable,

that it would be a complete loss of time to enter into the detail. Speculations of this kind, respecting the internal state of this or any other planetary body, add very little to our information, even if they gratify our curiosity.

The *Georgian* is the most remote planet in the system that has yet been discovered. It was first observed by Dr. Herschel, in 1781; its light is of a bluish white colour, and it subtends a visual angle of only four seconds of a degree, although the actual diameter is thirty-five thousand miles. It appears like a star of the sixth magnitude; its distance is one thousand eight hundred millions of miles from the sun, and it takes eighty-four years to make its revolution in its orbit. It is surrounded by six attendant moons, which were likewise discovered by Herschel.

To assist the memory, and form an idea of the proportional distance of each planetary body from the sun; if the distance of the Georgium were divided into one hundred and ninety parts, the proportional distance of the rest of the orbits would be as follow: Mercury five; Venus seven; the Earth ten; Mars fifteen; the Asteroids twenty-eight; Jupiter fifty-two, and Saturn ninety-five.

Comets unquestionably belong to our system, and are governed by the same laws as planetary bodies; but their number and periodic times appear to be very ill understood. In the time of

Whiston, Halley, and Newton, great attention was paid to this subject, and many calculations were made by these illustrious philosophers; but their labours however have been very ineffectual, for they have completely failed in every case of periodic times, saving one instance. It is true that some of the calculated periods have not yet arrived; but if we may judge from what is past, we have very little hope for the future.

The comet of 1680 has been calculated by Newton to have a periodic time of five hundred and twenty-eight years; this leaves sufficient time for speculation, and a future age can only determine the accuracy. If the laws could be discovered, we are well assured that we should find the same immutable principles operating in this part of creation, as well as in any other. The comet of seventy-five years is a sufficient proof of this observation; it was first noticed in 1531, then in 1607, 1682, 1758, and consequently will appear again in 1833.

Comets revolve in highly eccentric orbits. The comet of 1680, was calculated by Newton to have approached within one hundred thousand miles of the sun's surface, when he supposed it received an influence of heat two thousand times greater than that of red hot iron. Its velocity in this part of its orbit was supposed to be about eight hundred and eighty thousand miles an hour.

This century has already produced two comets

of very striking appearances; one was peculiarly interesting, from its long duration and very visible effects.

The comet may be divided into three parts, the nucleus, coma, and tail.

The nucleus, or central part, is of very small diameter, and is, no doubt, the actual body. The coma is probably nothing more than a dense atmosphere, which surrounds the comet, and expands as it approaches nearer the sun. The tail is probably an effect of refraction or condensation of solar rays, produced by passing through the cometary atmosphere. The tail of the last comet which appeared was calculated to extend through a space of twenty-four millions of miles; it was always in opposition to the sun, and the light so dilute that stars could be distinctly seen through it.

It would be too extravagant to suppose that this tail had any actual communication with the comet, or that it was the result of a constant combustion upon its surface; the general appearance and effects could not be explained by any such supposition. Newton himself imagines that there is an exceeding subtile ether diffused through infinite space; this may probably enough have sufficient density to reflect the issuing rays of solar light, after they have been refracted and condensed in passing through the cometary atmosphere. If this hypothesis be admitted, it will

account for the dilute light and great extent of the tail, and also for its constant opposition to the sun.

When we reflect on the magnificence of the great picture of the universe, the outline of which we have been considering, we are lost in the grandeur and immensity of the prospect; so that on returning to the contemplation of the surrounding objects and ourselves, we cannot help feeling our own insignificance in the material world. But still the mind endeavours to raise itself above those restraints which nature has imposed upon the body, and to penetrate into the abyss of space in search of congenial existences.

In speculations of this kind, reason and argument must, in all cases, give way to conjecture and imagination; and thus we are led from the solid basis of philosophy, to wander into the region of fiction, and become more immediately connected with poetical than geometrical figures; between which, it must be allowed, there is no very happy coincidence; for the poet communicates but a few facts, and these he wishes to expand and diversify; he dwells on a favourite idea, and represents it in a great variety of emblematical forms; for it is his object to say a little very elegantly, but in circuitous and somewhat exaggerated terms.

The information which the natural philosopher has to impart, is too copious to allow prolixity

in the detail; the subjects are in general too intricate to be compatible with digressions after amusement; and if he pleases, it must be by gratifying the love of truth, and satisfying a thirst after knowledge.

Some of the succeeding observations may probably be considered as more imaginary than real views of philosophy; but still, in subjects of such universal interest, the principle will not be too severely scrutinized.

If we may be suffered to indulge in speculations concerning the surrounding worlds, the *moon* will naturally become the first object of our attention, on account of its proximity to the earth.

If this globular opaque mass be inhabited, it must be by beings capable of living with very little air, and still less water. Dr. Herschel is of opinion that the moon's atmosphere is less than a mile high, and exceedingly rare, so that the sun must shine without intermission for a fortnight together, upon the same part of its unclouded surface, without having its heat moderated by the interposition of air, or by the evaporation of moisture.

The want of water upon the surface of the moon, is not only inferred from the want of an atmosphere, but likewise from the irregular appearance of the margin of the moon during an eclipse of the earth; for there is no part

sufficiently uniform to allow us to suppose it to be the surface of a fluid.

As the moon only revolves once round her axis in her revolution round the earth, the lunar inhabitants can have but one day and night, which must be about a fortnight each.

The same face of the moon is constantly turned towards us, and this appears very rocky and barren, as if it had been subject to frequent disturbance from volcanos. Herschel describes one that he has frequently observed in an acting state.

La Place is of opinion that the meteoric stones or aërolites which frequently fall upon the surface of the earth, are projected from lunar volcanos beyond the influence of the moon's attraction. He calculates that if the force be four times greater than that of a cannon ball, at the moment of its discharge, or about eight thousand miles in a second, it will be sufficient to effect this projection; and that these stones in falling through the atmosphere, will generate so much heat by compressing the air as to produce the appearance of fiery meteors, and raise the stones to a high temperature.

If we turn our eyes from the moon to those planetary bodies that are revolving round the sun, in their respective orbits, we are peculiarly interested with the striking analogy that exists between them and our earth, and feel induced to

conclude that they are destined by the Creator for the same purposes. Yet, if they be habitable worlds, the constitution of organic and inorganic matter must be very different from ours. Water, for instance, could not exist in a fluid state upon any of the superior planets; and it would be instantly converted into vapour upon the surface of either Mercury or Venus.

If the sun be the source of heat, it is probable that the mean heat of Mercury would boil quicksilver; and, therefore, its inhabitants must be constituted very different from ourselves.

The sun's diameter, observed from Mercury, would appear more than twice as great as it does to us upon the earth.

The climate of *Venus* must be much more temperate than that of Mercury; and although in many respects it resembles our earth, yet the heat would be much too great for animals and vegetables, such as ours.

When the earth is in opposition to the sun, it must appear four times as bright to an inhabitant of Venus, as this planet does to us, and may probably be visible during the day. This appearance, with that of the moon, must have a very interesting effect.

The climate of *Mars* is as much colder than ours, as Venus is hotter; in other respects there is no very striking difference. Dr. Herschel has observed a constant appearance of two bright

spots, or circles, near the poles of Mars, which he attributes to the ice and snow perpetually surrounding them. It is not, however, probable that water would remain fluid in any part of this planet; even quicksilver, or alcohol, would be frozen in its most temperate climes.

It seems doubtful whether *Ceres, Pallas, Juno,* and *Vesta,* which have been recently discovered, would be sufficiently solid to give firm footing to any material beings. A person from this earth transported thither, would only weigh a very few pounds. It is generally supposed that the largest of them is not more than two hundred miles in diameter.

It is obvious that the most striking feature of the heavens, observed from *Jupiter,* would be the diversified positions and combinations of his four moons. Their light must be faint, but yet of great importance during his short nights, which are uniformly five hours long, independently of twilight.

The axis of Jupiter being very nearly perpendicular to the plane of its orbit, the inhabitants of this vast globe must have an unvaried season throughout the whole revolution of the planet. Jupiter's year contains about ten thousand of his days.

Our earth, most probably, is always invisible to a spectator situated on Jupiter, on account of its apparent proximity to the sun; in the same

manner as a planet at half the distance from Mercury would be invisible to us.

The planet *Saturn* is about one thousand times larger than the earth. The great peculiarity of this planet consists of a prodigious ring, which entirely surrounds it. This must produce on different parts of the surface of the planet, very diversified appearances of magnificent luminous arches, stretched across the heavens, especially in that hemisphere which is on the same side of the ring with the sun.

Saturn has likewise his seven moons, which must produce an abundant quantity of reflected light to his inhabitants, and compensate, in some measure, for the dilute light which it receives from the sun at the distance of nine hundred millions of miles.

From the *Georgian* the sun would seem like a little star, not one hundred and fiftieth part so bright as he appears to us, and all the rest of the planetary bodies, saving Saturn and Jupiter, would doubtless be invisible.

The next and last part of this sublime subject takes us from our planetary system into the *starry heavens*, where the unbounded mind springs to its maker, and exulting in its own perfections, views the rise and fall of systems, as we view the mutability of our own nature, and looks to the infinite extent of creation as an immense machine,

operating under the influence of matter and motion.

These bright orbs which are diffused through the apparently concave sphere of the heavens, have long been called fixed stars, because it was supposed they never changed their position with respect to each other; but the labours of Maskelyne and Herschel have proved that this universe of stars is full of motion; and yet, on account of their prodigious distance from us, so small is the angular variation, that even in a hundred years, those that have the greatest apparent motion, do not vary their situation more than four minutes of a degree. What a glorious view of order and extent is thus presented to our imagination! Millions of suns surrounded by myriads of imperceptible earths, all governed by the same principles of nature, universal and immutable, eternally performing their revolutions, and glorifying the power of their Creator.

Yet these masses are not of eternal duration. Since the commencement of the christian æra, many new stars have been observed, and the Alexandrian catalogue shews us that many have disappeared; even the time of them has been particularly noticed.

Some stars have been suddenly observed of a superior degree of brightness, which has kept constantly increasing for a short period, until it

has obtained its maximum; the light then began gradually to diminish, until the star ultimately disappeared.

There are other stars which have a periodic time, or keep increasing in brightness for a certain number of days; the brightness then gradually lessens, and after a limited period returns again.

Thus it seems that there is as much mutability amongst the stars as upon the surface of the earth. And why not? We must suppose there is a kindred relation amongst the laws of creation, although the masses may be dispersed at prodigious distances from each other.

We are told, on the most sacred authority, that our own bodies were formed from the dust, and that they return to dust again. How strictly this agrees with those chemical changes which we daily observe.

When the animal body is no longer required as a tenement for our eternal spirit, the chemical hand of nature commences its decomposing influence, and mixes it with the earth, until the inorganic state is changed through the medium of the vegetable creation.

Water holds elementary substances in solution; the absorbent vessels of vegetables take them up, and the vital processes of nature convert them into an organic form, fit for the food of animals. How admirable these combinations! What mutual dependence they possess, and how sublimely they form the circling chain of nature!

Then what have we in our own bodies that is not in common with the earth; and why may not those numberless orbs that are scattered through the wide expanse of heaven's vault, be as subject to decomposition as ourselves, for purposes which we cannot develope in the present finite state of our being.

We believe that the earth is given to man as a temporary residence, that he may render himself more worthy of the presence of his Creator, and become more fit for the abode of the blessed. We see thousands of suns like our own, and conclude from analogy, that they have millions of imperceptible earths revolving round them; inhabited by multiplied myriads of living creatures like ourselves.

What a delightful and glorious view this gives us of the works of Omnipotence; but we have still higher considerations,—we have to preserve an eternal spirit, in his glorious presence, when these stupendous masses are crumbled into nothing.

We, therefore, look from this earth to heaven, and animated with hope, through the intercession of the blessed Jesus, wait for that happy moment, when the mortal puts on immortality; when we are raised from the dust to the footstool of the Creator, to partake of those eternal joys which the eye has not seen, the ear heard, or has it entered into the heart of man to conceive.

A SKETCH

OF THE PROGRESS OF

PHILOSOPHICAL

AND

CHEMICAL

SCIENCE.

NATURAL PHILOSOPHY.

IN a general illustration of the sciences, it frequently becomes necessary to refer to the different authors who have been instrumental in promoting them. In the wide field of natural philosophy this is peculiarly the case, for the progress that is made in it has not been derived from occasional bursts of splendid talents, but from the uniform and persevering labours of numerous persons for upwards of two thousand years. On this account a brief historical view of the progressive discoveries, and the names of the authors, in chronological order, may not only form an amusing but a useful appendix to the preceding work, by producing in the mind a clear and distinct arrangement of those particular facts on which so much of the subject depends.

We are very imperfectly acquainted with the state of physical science amongst the Egyptians; we are in possession of numerous monumental remains, with characters indelibly stamped upon the surface, which would no doubt give us many important and interesting facts; but unfortunately

we are completely shut out from this source by our total ignorance of the characters.

We are however assured, that the superior excellence of the arts and sciences in Egypt attracted the attention of distant states, and that the rising colonies of the Greeks derived their first elements of mathematical, mechanical, and astronomical learning from amongst them. *Thales* and *Pythagoras*, about five or six hundred years before the christian æra, were employed on this important mission; and after an absence of some years from their native country, returned to communicate their respective acquirements to their different disciples.

Philosophy is indebted to *Pythagoras*, not only for its foundation, but its name. His predecessors had been in the habit of calling themselves wise; but *Pythagoras* chose to be denominated a lover of wisdom only, and from the greek of this expression, is derived the name Philosophy.

It is said that *Pythagoras* was acquainted with the laws of gravitation; and asserted, that the earth and the planetary bodies revolved round the sun: it is added, that *Copernicus* received this idea from his disciples, who are mentioned by *Plutarch* as having propagated the principles of their master. Be this as it may, it is however certain, that *Pythagoras* made considerable improvements, both in the mathematics and mechanics. He was the first that discovered the well

known relation between the hypothenuse and the sides of a right angled triangle; or demonstrated that the square of the hypothenuse is always equal to the sum of the square of the sides.

Aristotle, about two hundred years after *Pythagoras,* laid down the law of the composition of motion; his talents in elegant literature, as well as in natural history and natural philosophy, are sufficiently established.

The foundation of *Alexandria,* forms the commencement of a memorable period for science in general; but more particularly for mathematics and astronomy.

Amongst those who studied in this school, the sciences are indebted to none more than to *Euclid,* who lived about three hundred years before our æra. It is uncertain how much of his elements may have been derived from his own investigation; but the masterly manner in which this well known work is arranged, and the precision and accuracy which it possesses, demands nearly as much praise as would be due to an original discoverer.

Epicurus was a cotemporary of *Euclid,* and the last of the Pythagorean school; he shewed great penetration in assigning the true causes to many mechanical phænomena.

Appollonius of *Perga,* lived about half a century later: the method of analysis is generally ascribed to *Plato;* but it is very frequently

employed both by *Appollonius* and *Pappus*. *Plato* was the discoverer of the conic sections; but *Appollonius* investigated some of the most abstruse properties, and left but little to be added by more modern geometricians.

For the demonstration of the fundamental properties of the lever and of the centre of gravity; for the discovery of the laws of hydrostatics, and the method of determining the specific gravity of bodies; for the construction of the first cranes, and of the first planetarium, and for those improvements of the method of mathematical investigation, which have been the basis of every modern refinement in analytical calculation; for all these additions to our knowledge and power, we are indebted to *Archimedes*. He lived two hundred and eighty-seven years before the christian æra, and his works were printed at Oxford, *in* 1792.

This celebrated philosopher, warmed with the sublimity of his science, and depending upon the validity of his arguments, boasted that if he had another earth to which he could step over, he would draw the whole of the present sphere out of its place.

Hiero, king of Syracuse, surprised at the boldness of his assertion, requested him to give some substantial proof of its truth, by moving a great weight with a small power: upon this *Archimedes* procured a ship, which was with great labour drawn on shore; and having

completely manned and freighted it, he seated himself at a distance, and by slightly touching the first movement of a machine, he drew it along as smoothly and as safely as if it had been sailing in the deepest water.

The science of hydrostatics, in particular, received great advantages from this eminent mathematician. He discovered the mode of measuring a solid, and ascertaining its specific gravity, by immersing it in a fluid: it is said to have occurred to him on entering a public bath, and that he felt such extacy at the thought, that he ran home naked, crying out "I have found it, I have found it."

Archimedes, being called upon by *Hiero,* at this time, to ascertain the adulteration that had been made in a crown of gold, by a fraudulent goldsmith, (who imagined that on account of the complicated form of the work, he should escape detection,) employed the law he had just discovered, to ascertain its specific gravity and that of the gold, which ought to have been used, by which means he readily detected the quantity of the alloy.

Archimedes discovered that a sphere was equal to two-thirds of a circumscribing cylinder, both in surface and solidity. He was so much pleased with this discovery that it was put upon his tomb, and was the very means by which *Cicero* discovered the place of his interment, at Syracuse.

He also discovered that a circle is equal to a triangle, whose base is equal to the circumference and height to the radius; so that if radius be unity, the circumference will be less than $3\frac{1}{7}$.

The subject of optics was likewise much improved by this noble philosopher. It is said that he made a compound burning mirror of sufficient power to set fire to the Roman ships at the time of the siege of Syracuse. However this circumstance may be doubted under its present form, it is well known that *Buffon* has shewn the practicability of burning bodies at a considerable distance, by a collection of plain mirrors.

Archimedes considered practical mechanics so far beneath his consideration, that he thought it unworthy of himself to leave any written treatise behind him upon this subject; he rested all his hopes of fame upon those works which exhibited the magnificent and elegant, uncontaminated by the imperfections of the material world.

It is said, that at the siege of Syracuse, the Roman General *Marcellus*, had given express orders that the life of *Archimedes* should be saved; but through inattention he was killed by a Roman soldier, in the act of study.

The forcing-pump and fire-engine were the invention of *Ctesibius*, of Alexandria, the greatest mechanic of antiquity after *Archimedes*. *Ctesibius* is supposed to have been the son of a barber, and

to have had his attention turned to mechanics, from being employed by his father to fit a shutter with a counterpoise for his shop window.

Being shut out from the knowledge of the Egyptians, we may fairly refer the commencement of the period of astronomical science, to the school of Alexandria.

The oldest astronomical observations on record, were made at Babylon, seven hundred and twenty years before the christian æra, and were transmitted by *Ptolemy*, who employed them for determining the moon's mean motion.

Thales brought astronomy from Egypt, seven hundred years before our æra; he taught the sphericity of the earth, and the obliquity of the ecliptic; he also predicted an eclipse of the sun, which put an end to a furious war, by happening in the midst of a battle.

Pythagoras, who followed *Thales* into Egypt, profited by the information which the latter had obtained; and, it is conjectured, he was acquainted with the diurnal and annual motion of the earth, which was afterwards taught by his disciples; but still the first source of accurate and continued observations belongs to the professors of Alexandria.

After the death of *Alexander*, and the subsequent division of his empire, the province of Egypt fell to *Ptolemy Soter*, whose love of science and munificence to its followers, attracted a

number of learned men from Greece to his capital. His son *Ptolemy Philadelphus,* continued these advantages, and built an observatory, which he furnished with necessary books and instruments. *Aristarchus, Hipparchus,* and some others, successively taught; but the last and greatest astronomer was *Ptolemy* of Ptolemais, in Egypt, who existed a very few years before the commencement of our æra. He was, however, too much influenced by the visible appearances of the heavens, which led him to construct a system that supposed the sun and planetary bodies to revolve round the earth.

Aristyllus and *Timocharis* were the two first astronomers that made observations in the observatory of Alexandria; they observed the positions of all the principal stars in the zodiac, which *Ptolemy* subsequently examined, and gave a corrected catalogue of the latitude and longitude of all the visible stars, amounting to one thousand and twenty-two.

Hipparchus was peculiarly distinguished for his astronomical knowledge; he was a professor in the Alexandrian school, about one hundred and sixty years before Christ, and determined the length of the year to be three hundred and sixty five days, five hours, and fifty-five minutes; he also shewed that the sun's motion was greater in winter than in summer, and determined the inclination of the moon's orbit to the plane of the ecliptic, to be about five degrees.

Hipparchus calculated the distance of the sun from the earth to be one thousand and two hundred semidiameters of the earth, and made the horizontal parallax equal to three minutes.

He also made the first known catalogue of the stars, and discovered the precession of the equinoxes to be two degrees in one hundred and fifty years, by comparing his observations with those of *Aristyllus* and *Timocharis*. *Hipparchus* also constructed a solid sphere, and placed the stars upon it.

With the last of the *Ptolemies*, fell the Alexandrian school, by the barbarous irruption of the Mahometans; learning and science were soon wrapt in darkness, and trodden under foot by *Vandalism*, for many ages. We are however indebted to the *Caliph Abdalla Almanon*, an Arabian philosopher at Bagdad, in 814, of the christian æra, for collecting the writings of *Ptolemy* and others, and translating them into Arabic. The greatest work of *Ptolemy*, which is now extant, is called the "Almageste," being first known to Europe by a translation from the Arabic.

In the midst of this wretched age of ignorance, an insulated individual arrests our attention, by merits of no ordinary kind; this was *Roger Bacon*, who was born at Ilchester, in the year 1214. His pursuits in chemistry, led him to discover gunpowder, but it is stated that from humane

motives he withheld the composition from the public. From his knowledge in optics, he constructed the magic lantern and other curious optical instruments, which are supposed to have been employed by designing men in that day to promote the objects of superstition. Towards the end of the fifteenth century science began to revive, and a number of men of the most distinguished ability very rapidly succeeded each other.

Copernicus was born at Thorn, in Prussia, in the year 1473, and gave a new view of the planetary system, in direct opposition to that which had been received by *Ptolemy*.

It is said that *Plutarch* furnished *Copernicus* with his first idea upon this subject, by stating that *Philolaus*, a disciple of *Pythagoras*, had, according to the principles of his master, placed the sun in the centre of the system, and made the earth turn round it. He also accounted for the apparent diurnal motion of the heavens round the earth, by supposing the earth to turn round its axis.

Copernicus closely studied his system for thirty-six years before he thought it sufficiently matured to give to the world. It appeared, in 1543, under the title of "De Revolutionibus Cælestibus," in six books, and he died in a few days after the work was published.

Tycho Brahé, a nobleman of distinguished talents, either from vanity or religious scruple,

thought proper to oppose the system of *Copernicus*, and endeavoured to establish a theory of his own, which might agree better with the principles of bigotry and superstition that had not yet expired, with the long and dark age that fostered them.

The opinions of *Tycho* succeeded for some little time; but the light of reason that was now dawning with the incipient state of science, soon rejected the complicated system that had been imposed upon it; and the doctrine of *Copernicus* was again revived and established, with the sanction of *Newton* and many other astronomers of the most resplendent talents.

Tycho Brahé was born in 1546; he discovered a new star in Cassiopea, which had only a duration of about one year and half. Frederic, King of Denmark, gave him Huen Island, in the Baltic, where he built the famous observatory of Uraniburg, and determined the places of a thousand stars with much more accuracy than *Ptolemy*.

Ptolemy was acquainted with atmospherical refraction; but *Tycho* determined the laws that govern it. He was likewise the first who ascertained that comets were not meteors, but were much further off than the moon.

Kepler, the pupil and assistant of *Tycho Brahé*, was a man of extraordinary talents, and added considerably to astronomical and mathematical knowledge. He was the first that brought optics

to a science, by publishing his "Dioplrics," in 1611. The telescope is usually attributed to *Jans* or *Galileo;* but *Kepler* was the first who reduced the theory of the telescope to its true principles. He laid down the common rules for finding the focal length of simple lenses, and shewed how to determine the magnifying power of the telescope.

Kepler became a zealous defender of the system of *Copernicus,* and discovered that if an imaginary line be drawn from the sun to a planet, it always describes equal areas in equal times. He also discovered another sublime law of nature, which is, that the squares of the times of the revolutions of the planets are always proportional to the cubes of their mean distances from the sun; and that this law applies equally to secondaries as to primaries.

Galileo, about the year 1600, greatly enriched philosophical science, by ascertaining the pressure of the atmosphere. It was generally supposed, before this period, that water rose in the cylinder of a pump, from nature's abhorrence of a vacuum; but *Galileo* reasoned like a true philosopher, and considered if this were the means of its ascent, the water would rise to an unlimited height. He observed that the ascent was confined to thirty-four feet, and concluded, that a column of water of this height was equal to the pressure of a column of the atmosphere of the same base; this

was confirmed by *Torricelli*, who shewed that a column of mercury was only supported when its weight was equal to that of a column of the atmosphere of the same base.

Galileo having heard that *Jans*, a Dutchman, had discovered the telescope, immediately made one that magnified thirty-three times. On the 8th of January, 1610, he discovered three of Jupiter's satellites, and soon afterwards the fourth. He observed that Venus had phases like the moon, and noticed spots on the sun's disk; but his telescope had not sufficient power to shew Saturn's ring; this was left for the instrument improved by *Huygens*, who observed that the milky way was composed of innumerable stars imperceptible to the naked eye.

Science owes much to the labour and talents of *Galileo*; but his character, like the spots on the sun which he had discovered, received a blemish that time cannot wipe away. The Roman Inquisition hearing that *Galileo* was warmly espousing and propagating the system of *Copernicus*, summoned him before them, to answer for the heretical opinions which it contained. Awed by the secret tribunal, and anxious for his own safety, he swore that he did not believe the principles which he had been supporting, and signed a declaration, that was immediately published to the world, in which he wholly abjured the principles of *Copernicus*. This fatal error is said to

have preyed so much upon the mind of this great man, that he ultimately died of a broken heart.

Descartes was born in 1596; he connected geometry with algebraical analysis. He likewise shewed that every curve might be formed by the action of a straight line along the axis of the curve, while a point moving along this line, according to a certain law, describes the curve. The line intercepted between the axis and the curve, is called the ordinate; and the part of the axis intercepted between the ordinate and the apex of the curve, is called the abscisse.

Descartes gave the first satisfactory explanation of the rainbow, and supposed that the effects of light were produced by the undulations of a highly elastic fluid. He also conceived the planets to have their revolutions, by being placed in supposed vortices.

In the year 1654, *Otho von Guericke* first constructed a machine similar to the air-pump, by inserting a small pump in a cask of water, so that when the water was drawn out, a tolerable void was produced in the cask.

In 1658, *Hooke* finished an air-pump for *Boyle*, which was more convenient than *Guericke's*; this was afterwards improved by *Boyle*, and employed for numerous judicious experiments, on the mechanical properties of air.

Hooke introduced some important experiments on the elasticity of air, and was the first who

applied the balance spring to watches; he also improved the mode of employing pendulums in clocks. The quadrant, telescope, and microscope, were likewise indebted to him for some of their greatest improvements.

Hooke conceived that it was the power of gravity which kept the planets in their orbits. This notion is, however, as old as the time of *Lucretius*, and is particularly noticed by *Kepler*. *Newton's* great claim is for discovering the laws.

Hooke was one of the first members of the Royal Society, which was established April 22d, 1663. His principal work was the "Micographia," and another, called "Lampas," was also published by him.

We now come to the time of our immortal *Newton*, who was the pride of his country, and the ornament of mankind; he was born on Christmas-day, 1642. At twelve years of age he was sent to school, at Grantham, and gave very early indications of a mechanical genius, by making a wind-mill, water-clock, and paper-kites. He also made a sun-dial, by means of pegs stuck in the roof of a house. At the age of eighteen, he went to Cambridge, and laid the foundation of his admirable method of fluxions, before he was twenty-four years old.

His first optical experiments were made in the year 1666, and were soon afterwards communicated to the Royal Society. He was admitted a

member in 1671; and, although he possessed family estates of two hundred pounds a year, a dispensation was passed in the society, that he should be excused from the customary payment of a member, which was a shilling a week.

The theory of gravitation, and the mechanics of the universe, are developed in his "Mathematical Principles of Natural Philosophy," first published in 1687. The following year he was chosen representative of the University of Cambridge; and in 1696, he was appointed to a lucrative situation in the Mint. From 1703, until his death, in 1727, he continued President of the Royal Society. He was knighted by Queen Anne, and died possessed of considerable property.

Dr. *Horsely* published his works in five quarto volumes, in 1779, except some religious papers on the Trinity, which unfortunately did not exactly square with the rigid orthodox opinions of this high and learned priest, and were therefore suppressed.

Pemberton who has given the philosophy of *Newton* a more popular and attractive form, says that when *Newton* was one day alone in his garden, he fell into a speculation on the power of gravity; and having found that this power was not sensibly diminished at the remotest distance from the centre of the earth to which man can rise, he thought it reasonable to conclude that

this power might extend to the moon, and that she might probably be retained by it in her revolution, as a stone is retained in a sling by the hand; and that even the whole of the planetary bodies might be kept in their respective orbits by the same power. The result of these investigations have proved that his speculations were well founded, and that it is this principle of attraction which governs the universe.

Leibnitz was a philosopher of great mathematical reputation; he was born in 1646. He invented the differential calculus, which was considered the same as the fluctionary calculus of *Newton*, the notation excepted: what *Newton* expressed by x, *Leibnitz* expressed by dx.

This led to very great disputes between these two eminent mathematicians, as to the priority of the discovery; and the subject excited the greatest interest amongst the philosophers of that day.

Leibnitz was so little satisfied with their opinions, that he applied to the Royal Society to request that they would form a committee to examine his claim, and report upon the subject. The committee determined that *Newton* had his method before the year 1669; and *Leibnitz* not till 1677, a year after the communication of a letter from *Newton* to him, from which he might easily have formed an idea of *Newton's* method.

In 1675, the Royal Observatory at Greenwich

was founded, and *Flamsted* was made astronomer royal, with a salary of one hundred pounds a year. He was afterwards expelled the Royal Society, because he would not pay the annual contribution from which *Newton* had been exempted. *Flamsted* gave the exact position of three thousand stars.

Halley succeeded *Flamsted* at the Royal Observatory. He made a voyage towards the south pole, to ascertain the variation of the magnetic needle; and, at St. Helena, determined the places of three hundred and fifty stars in the southern hemisphere.

He rendered great service to science generally, and more particularly to the subject of astronomy, by laying down a mode of computing the true distance of the sun from the earth, by means of two transits of Venus, which he calculated would happen in 1761 and 1769. From the transit of 1761, Dr. *Maskelyne*, at the Cape of Good Hope, determined the sun's horizontal parallax to be 8.5 seconds. In 1769, *Dymond* and *Wales* were sent to Hudson's Bay. *Cook*, *Green*, *Banks*, and *Solander*, to Otaheite. *Call* to Madras; and *Mason* to the North Cape, to observe the second transit of Venus. The mean result of their observations determined the horizontal parallax to be 8″.6

Cassini and *Rœmer* discovered the velocity of light to be two hundred thousand miles in a

second, from observations on the eclipses of Jupiter's first satellite, which happen sometimes eight minutes and a quarter sooner, and sometimes eight minutes and a quarter later than the equated time.

Cassini likewise discovered four of Saturn's satellites; *Huygens* one, and Dr. *Herschel* two.

The pendulum clock and micrometer were discovered by *Huygens.*

In 1671, a clock that beat seconds at Paris, was found to lose time at Cayenne, so that it became necessary to shorten the pendulum: this induced *Huygens* to suppose that the earth was an oblate spheroid, which led to the determination of the length of a degree of the earth, on the meridian in the torrid and frigid zone.

Bradley succeeded Dr. *Halley,* at Greenwich; he was born in 1692, and made many very important discoveries.

He observed an annual change of declination amongst the fixed stars, from the mutation of the earth's axis, which takes eighteen years to complete its revolution. *Bradley* also discovered the aberration of light, compounded of its progressive motion from the sun and the motion of the earth.

We come now to the eighteenth century, when natural philosophy, ripened by the talents of preceding ages, bursts forth in its greatest lustre, supported by men of most distinguished talents in

different parts of Europe; many of whom are still living to receive the honourable reward of their labours; viz. public praise and public gratitude. It would be tedious and unnecessary to descend to the particulars of those discoveries which are fresh in the recollection of every man that possesses a small share of science; it will be enough to point out some of those which have had the most important effects in bringing us still better acquainted with the mechanical procedure of nature.

Amongst the most conspicuous of those who have enriched the arts and sciences with their labours, is Mr. *Watt*, a man peculiarly distinguished for the improvements which he has made in the construction of the steam-engine. The hazardous operation, and limited power of the first engines, which were constructed by Captain *Thomas Savery*, rendered them almost useless; and the improvements that were afterwards made by *John Newcomen*, added but little to their power, although it increased their security. In a country like this, that owes its greatness to the extent of its commerce, it requires an equivalent improvement in the arts and manufactures to keep pace with it. This can only be effected through the medium of mechanic power, and for the obtainment of active and infinite force, we are indebted to the elasticity and condensibility of steam; this is the primary agent of the

steam-engine, which, in the able hands of Mr. *Watt*, has been brought to such a state of perfection, as to leave but little room for improvement.

The arts likewise owe great obligation to *Harrison*, for having constructed watches with sufficient accuracy for determining longitude to a considerable degree of precision. In 1765, he received ten thousand pounds for his labours, from the Board of Longitude.

Dolland has the honour of having invented achromatic telescopes. He made some experiments on the refraction of different kinds of glass, and having discovered a material difference between the dispersive properties of flint and crown glass, he combined them so as to produce lenses, in a great measure free from the aberration of light, and those primitive colours which had long been a cause of complaint, and a source of considerable error, in telescopes of earlier construction.

Optics and astronomy are particularly indebted to *Herschel*, for having brought the reflecting telescope to a degree of perfection, far exceeding any thing that had been done before. Practical astronomy has derived incalculable advantages from his numerous observations; he has added one primary body and eight satellites, that were unknown before to our system, and was the first that separated the rays of heat from those of light, by means of refraction.

Maskelyne ascertained that the stars which had received the name of fixed stars, from the earliest periods, had all of them an independent motion, more or less visible, according to their direction.

The labours of *La Place* in the science of astronomy, have greatly extended the doctrines of *Newton.* It has been elegantly said of him, that if *Newton* could rise again, he would have to re-study his own principles.

The preceding names form but a small proportion in the catalogue of the present day; the science of natural philosophy has not only received eminent support in our own country from a great number of enlightened men; but the Continent of Europe and America have likewise largely contributed to these general interests of mankind. We have *D'Alembert* and *La Grange, Maclaurin* and *Euler, Smeaton, Arknright, Symington, Fulton, Rumford, Wollaston,* and many others, equally conspicuous for talents and eminence in arts and science.

CHEMISTRY.

CHEMICAL science, compared with Natural Philosophy, is of very modern date; but still it is neither less useful to society nor less interesting in its pursuit. As a constituent agent of nature, it possesses an influence as wide and extensive as its sister science; but its general laws and principles are by no means so well understood.

The chemistry of nature includes many of those changes with which we are intimately connected, and have the greatest interest. It is most materially concerned in the causes of rain, hail, snow, winds, volcanos, and even earthquakes. It is constantly operating amongst the particles of inorganic matter upon the earth, and is very conspicuous in the functions of animal and vegetable life; even the success of many arts and manufactures are wholly dependent upon it.

The cloathing of Egyptian Mummies affords us a most decided proof that this nation was admirably acquainted with the chemical art of dying. The great repute of the Tyrian cloths

also shews that the Phœnicians were not less celebrated in this respect; but whether these perfections arose from casual discovery, or from the knowledge of fundamental principles, is yet to be determined. The same impediment to the knowledge of Egyptian history, equally applies to chemical as to astronomical and philosophical sciences.

We are perfectly aware that the preparation of paints, enameling, the making of glass and porcelain, and the reducing of metals from their ores, as well as many other chemical arts, were perfectly well known to the Greeks and Romans; but it does not appear from any remains of their history, that they were at all acquainted with chemical principles; it is probable they were operations hit upon by chance, and cultivated to supply their luxuries or necessities, without any further consideration.

We hear nothing of chemistry in the Alexandrian school, and the dark ages of bigotry and superstition closed up this as well as every other avenue to light and reason. After fourteen hundred years of death-like torpor, man awakes again to assert his rights as a rational creature; and, as it were, to compensate for his loss of time, he endeavours to grasp at all those subtleties which, like the *ignis fatuus*, constantly elude his embrace, but still lead him on in the pursuit: this gave rise to the "*primumens*," the "*elixer*

vitæ," and all the witcheries of the philosopher's stone, which engaged the warmest attention of many distinguished men for some centuries.

When the furor of alchymical pursuit had in some measure subsided, and men of talent became sensible of their error, they began to take a new view of their numerous experiments, and examine the effects which had been produced, with a view to natural enquiry rather than any other object.

The pursuit of *Alchymy* died with *Paracelsus* and *Van Helmont;* and it may truly be said that the science of chemistry sprung out of its ashes; for the interesting effects which had been already observed, stimulated fresh enquiry, and the subject passed on with slow but gradual step for many years.

Boyle, about the middle of the seventeenth century, separated chemistry from pharmacy, and made many chemical as well as mechanical experiments on the properties of the atmosphere; but the nitro-aërial, or fire-making particles which were discovered by his assistant, Dr. *Hooke,* laid the first foundation for the present theory of combustion; this he has described in his Micographia; and twenty years afterwards in his Lampas, he gave a beautiful explanation of the principle by which a candle burns.

Mayow has great credit amongst many writers for his chemical principles, and it has even been stated that *Lavoissier* is wholly indebted to him

for his first ideas on the subject of combustion. It may perhaps be difficult to determine with respect to the latter circumstance; but as to the originality of *Mayow's* discoveries in combustion, it seems tolerably clear that he has borrowed his principle from *Hooke*. In his Essays, which he published at Oxford, about ten years after the Micographia, he has embraced *Hooke's* hypothesis, without having the candour to acknowledge it; and after having clogged it with some additions, he sends it forth as an effusion of his own brain.

Mayow's first and principal Essay contains some excellent experiments on air and respiration; but the most valuable part is his Chapter on Affinities.

The period at which chemistry assumed the character of legitimate science, may be referred to about the middle of the seventeenth century, when *Barner*, a physician to the king of Poland, published a methodical arrangement of all the facts that were generally known. This work is very scarce and valuable, as being the first that ranks chemistry amongst the sciences.

Bohine soon afterwards wrote a Philosophical Treatise on Chemistry: but *Becher* went much further than either of the other two; he collected all the discoveries that were then made, and described with great accuracy all the phænomena that were known. This work was published in 1669.

The celebrated *Stahl* was the pupil of *Becher*, and undertook to elucidate the doctrines of his master. In accounting for many chemical phænomena, he pretended to demonstrate the presence of a principle of inflammability, which he called phlogiston. He supposed that all inflammable bodies contained this principle, and when it was once separated from the substance, all combustion ceased.

The splendid talents of *Priestly* gave considerable eclat to the phlogistic theory of *Stahl*, which rendered it very universally received for a considerable time.

Priestly made many very important discoveries in pneumatic chemistry, which were highly advantageous to the science. He detected oxygen gas in the atmosphere, and formed a very ingenious theory to explain its effects in the lungs; but which, like many others in the abstruse department of animal chemistry, was found to be more fictitious than real.

He also discovered nitrous oxide gas, carbonic oxide gas, fluoric acid gas, muriatic acid gas, and ammoniacal gas. He, unfortunately for himself and the real interests of science, was supposed to mix too much religion and politics in his pursuits, which induced an illjudging populace to attack him in his house, at Birmingham, and to the great disgrace of the police it was burnt to the ground. Thus the scientific labours of many

years were destroyed, and science sustained an irreparable loss.

In 1795, he sought an asylum in America, to protect himself from the insults of this country, and died in 1804.

This period was peculiarly fertile in chemical talents; amongst the various professors there was none more particularly distinguished than Dr. *Black*, not only for his laborious investigations and particular discoveries, but likewise for the very able and useful manner in which they were communicated to his chemical students.

Black was the pupil of *Cullen*, and may be said to have been the first that commenced the subject of philosophical chemistry. *Black's* first discovery of fixed air, or carbonic acid gas, was in the year 1753. In 1762, he perfected and published his important theory of active and latent heat, which has laid this subtle subject on such a solid foundation that it has not since been disturbed. In 1766, he was appointed to the professor's chair at Edinburgh, which he filled with unblemished reputation for thirty years, and died at the age of seventy-one.

Mr. *Henry Cavendish* prosecuted *Black's* theory with great labour and success; and in 1765, published in the Philosophical Transactions, an elaborate paper on carbonic acid gas and hydrogen gas; the latter of which he may be said to have discovered.

This eminent philosopher also analyzed the atmosphere, and found that it was composed of twenty-one parts oxygen and seventy-nine parts nitrogen; he also observed that the component parts were not liable to variation.

The last and greatest discovery of *Cavendish*, was the composition of nitrous acid; he found it to consist of one part by weight of azote, or nitrogen, and $2\frac{1}{3}$ parts of oxygen.

The names of *Priestly*, *Black*, and *Cavendish*, are eternally enrolled upon the monuments of chemical science; we must now turn our attention to the philosophers of the Continent, who were not less zealous, or less distinguished than British chemists, in promoting the interests of chemistry.

Amongst the foremost of these we must place *Lavoissier*, a man of princely fortune and brilliant talents; who, having spent many years of his life entirely devoted to his studies, fell by the hands of his ungrateful countrymen during the phrenzy of the French Revolution; he suffered on the 8th of May, 1794.

The beautiful theory of pneumatic chemistry, established by *Lavoissier*, has wholly subverted the principles of combustion which were introduced by *Stahl*, and supported by *Priestly*, *Cavendish*, and *Crawford*, who were the last of the phlogistic class; and *Kirwin* the first to

allow that the *inflammable principle* was only hydrogen.

The theory of *Lavoissier* supposes that in every case of combustion, oxygen combines with the burning body, and that the oxide, or original body, is increased in its weight, by the weight of the oxygen that has been taken up during combustion.

This theory accords with experiments; the phlogistic theory attributes combustion to the loss of a principle which, against all the laws and operations of nature, renders the inflammable body heavier by its loss.

The pneumatic principles of *Lavoissier* have been referred both to *Hooke* and *Mayow*.

It is often difficult for a man to trace the first source of his own ideas, and still much more for another; but of this we are certain, that *Lavoissier* has brought the subject into a tangible state, which had never been effected by the imperfect conclusions of his predecessors.

Lavoissier ascertained the constituents of sulphuric acid, phosphoric acid, carbonic acid, and the metallic oxides. He also established the composition of alcohol, oils, and sugar, and the ingredients of animal and vegetable bodies.

Bergman, in Sweden, has been peculiarly instrumental in extending the subject of chemistry. He was the first that analyzed mineral waters and mineral bodies in general; he was

succeeded in this department by *Klaproth*, who greatly extended his discoveries of analysis. *Bergman* died in 1784.

Scheele was brought from a very humble situation, by *Bergman;* and, considering the few years he remained to ornament the paths of science, he may be considered as the most extraordinary chemist that ever existed.

He ascertained the nature of manganese, discovered the singular properties of oxymuriatic acid gas, and gave a theory of the composition of muriatic acid. He discovered a new earth, called barytes, and determined the constituents of the volatile alkali. These are all stated in *one* paper, which was published in 1772.

He discovered and ascertained the property of arsenious acid, oxalic acid, tartaric acid, malic acid, citric acid, fluoric acid, gallic acid, prussic acid, tungstic acid, molybdic acid, lactic acid, and uric acid. He ascertained the nature of plumbago and molybdena; analyzed fluor spar, and determined the composition of tungstate of lime; he also discovered oxygen gas without knowing of *Priestly's* experiments. This extraordinary man died in 1786, aged forty-four years.

Bertholet, in France, applied the oximuriatic gas, which *Scheele* had discovered, to the process of bleaching. The success was a little doubtful in the first instance; but from some subsequent improvements, the practice now universally

prevails, and the decomposition of vegetable colour which constitutes this operation, is now more effectually obtained in a few hours than five or six weeks, according to the old method.

This period was peculiarly productive of many more chemists of great celebrity, who enriched science with their labours; and if they did not add important discoveries of their own, they examined those of others, and greatly strengthened the principles which had already been established.

We are now brought to a new æra of chemical science; hitherto chemical affinity, the leading principle of nature in this department of her works, was as perfectly unknown as the general principle that constitutes attraction; but the scientific labours of *Davy* have greatly extended our views on this subject, by proving that all chemical combination depends upon the agency of electricity.

Before this subject is further developed, it will be necessary to give some brief account of the subject of electricity, from its first discovery.

Hawksbee, in the year 1705, observed that when mercury was shaken in a glass tube, it gave out light; and also that light might be produced from the friction of different substances on each other; and was the first that recognized the electricity of glass, by friction.

We are indebted to *Hawksbee* for the first rudiments of the electrical machine. He turned

a glass cylinder with a winch, and found that when the hand was rubbed upon it, it gave out electricity.

Gray divided bodies into conductors and non-conductors of electricity; and was the first who imagined that lightning and electricity were the same body.

Dufay formed the first theory of electrical action; he supposed that the electrical fluid was a compound, formed of two distinct elements, to which he gave the name of vitreous and resinous electricity. *Dufay* imagined that when these two elements were combined, there was no sensible electric effect; but if by any means they could be separated from each other, by electrics or non-conductors, they would constantly endeavour to reunite; which was the source of all electrical action. This was called the theory of the double current, from the disposition of these two elements to meet each other.

Franklin, about the year 1740, gave a new theory in opposition to that of *Dufay*. He supposed the electric fluid to be composed of elements entirely of the same kind, and that all electric action depended upon a plus and minus quantity, or the positive and negative state of bodies with respect to their electricity.

The simplicity of *Franklin's* theory was greatly preferred to the compound assumption of *Dufay*. Although the latter has had many able supporters,

it has been gradually giving way, and is now almost wholly forgotten; whilst the theory of *Franklin* is almost universally recognized by the electricians of the present day.

Dr. *Watson* lays in his claim to *Franklin's* principles, and says that he communicated similar opinions to the Royal Society some time before *Franklin's* theory was known in this country.

Muschenbroeck first discovered the effects of the Leyden phial; but *Franklin* explained the principle of its action.

Franklin confirmed the suppositions of *Gray*, and shewed the identity of lightning and the electric fluid, which gave rise to conductors for securing buildings from its effects.

The Board of Ordnance, in 1778, applied to the Royal Society to ascertain the best form of conductors for securing powder houses from the effects of lightning. *Cavendish* and *Franklin* recommended the upper end of the conductor to be pointed. *Wilson* and some others dissented, and insisted on the advantages of knobbed conductors.

These contending opinions, which were ultimately determined in favour of pointed conductors, produced a controversy in the society that lasted for some years, and caused more dissention among its members than had ever before taken place since its commencement.

Dr. *Priestly* discovered the conducting power

of charcoal, and made many improvements in electrical machines. *Ingenhouz* proposed the plate glass machine, which has been greatly improved by *Cuthbertson*.

Galvani, in 1790, observed a strong muscular action in the limbs of a skinned frog that happened to lie near his electrical machine during its action.

He is stated likewise to have impaled a frog upon an iron spike for the purpose of dissection; and having casually employed a silver probe in the operation, he found that when he completed the electric circuit, or made a regular communication between the animal, spike, and probe, a strong convulsive action was constantly observed in the limbs.

In consequence of these and similar experiments, *Galvani* formed his theory of animal electricity, which captivated by its novelty and ingenuity for some little time; but it was soon discovered that all his assumptions were perfectly gratuitous, and that he could not afford any proof of his principles.

Galvani supposed that animal muscles resembled a charged Leyden phial, having the inside plus and the outside minus. He conceived the nerves to be combined with the inside of the muscle, and that the will afforded a connection with the outside, by which means the surplus electricity was discharged, and produced the motions of the limb.

Volta discovered that the convulsions could be produced by touching any two parts of the same nerve or muscle, provided that two metals of different kinds were employed to form the electric circuit. This overthrew *Galvani's* hypothesis, and induced *Volta* to conclude that the electricity was evolved by the action of two metals on each other; and, after a laborious investigation of seven years, the voltaic pile was produced of plates of zinc and copper, which has done more in exploring the hidden recesses of chemistry than any other invention in the hands of man.

Volta, in 1800, sent an account of his pile to the Royal Society of this country.

Fabroni took up the same view as *Volta,* and endeavoured to shew that the whole of galvanism, as it was termed, depended upon the chemical action of two metals upon each other when they were placed in contact with certain fluids.

The first British experimenters were *Nicholson* and *Carslile,* who discovered that the zinc end of the pile was positive, and the copper end negative; and were the first that decomposed water by the influence of the galvanic fluid.

Cruickshank made a very important improvement in the apparatus, by uniting the zinc and copper plates, and afterwards fixing them vertically in a wooden trough.

He observed that the end of the positive wire reddened an infusion of litmus, and that the

negative end acted upon an infusion of Brazil wood. He concluded, from these effects, that an acid was evolved at the positive wire, and an alkali at the end of the negative wire.

Dr. *Henry* decomposed ammonia by galvanism, and Colonel *Haldane* found that the pile does not act under water or in vacuo.

The whole of the preceding discoveries form a very insignificant view of what has since been effected by the galvanic trough; it remained for Sir *H. Davy* to lay down the elements of chemical science by this apparatus, and employ it on his own principles, to analyze various bodies, and bring us better acquainted with their elements.

He assumed, as an axiom, that "all chemical affinity depends upon the electrical state of the elements that combine." And, inasmuch as bodies are only vehicles for a limited portion of electricity, the free electricity evolved from the electro-chemical apparatus, or galvanic trough, might be employed to decompose bodies that had not yet yielded to any other influence.

He substantiated his general axiom by passing acids through alkalis, and alkalis through acids, by means of the superior electrical energy of the apparatus; and rendered himself highly conspicuous in the eyes of Europe, by the decomposition of potash, soda, barytes, and strontian which had hitherto been considered as elementary substances.

Dr. *Wollaston* has identified electricity with galvanism, by performing the same experiment with each fluid; he has also shewn that a galvanic effect is produced in the action of the common electrical machine, by means of the amalgam which is spread upon the cushions.

Children has shewn that the quantity of electricity increases with the size of the plates; but the intensity with the number of pairs. This gentleman has very recently formed an electro-chemical apparatus of twenty plates, each plate six feet long and two feet wide, which possesses very extraordinary power in the deflagration of different metallic wires, and in other cases of combustion.

This brings us to a conclusion of our brief history of chemistry; but the present moment seems pregnant with discovery; the subject and the apparatus are almost equally new, and probably before many years are elapsed, the splendid talents that now adorn Europe will be enabled to remove the veil which envelopes some parts of the subject, and render the whole of the science of chemistry as perspicuous and conclusive as the principles of nature which constitute the laws of matter and motion.

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