A

LECTURE

ON

The Progress of Physical Science

SINCE THE OPENING OF

THE LONDON INSTITUTION.

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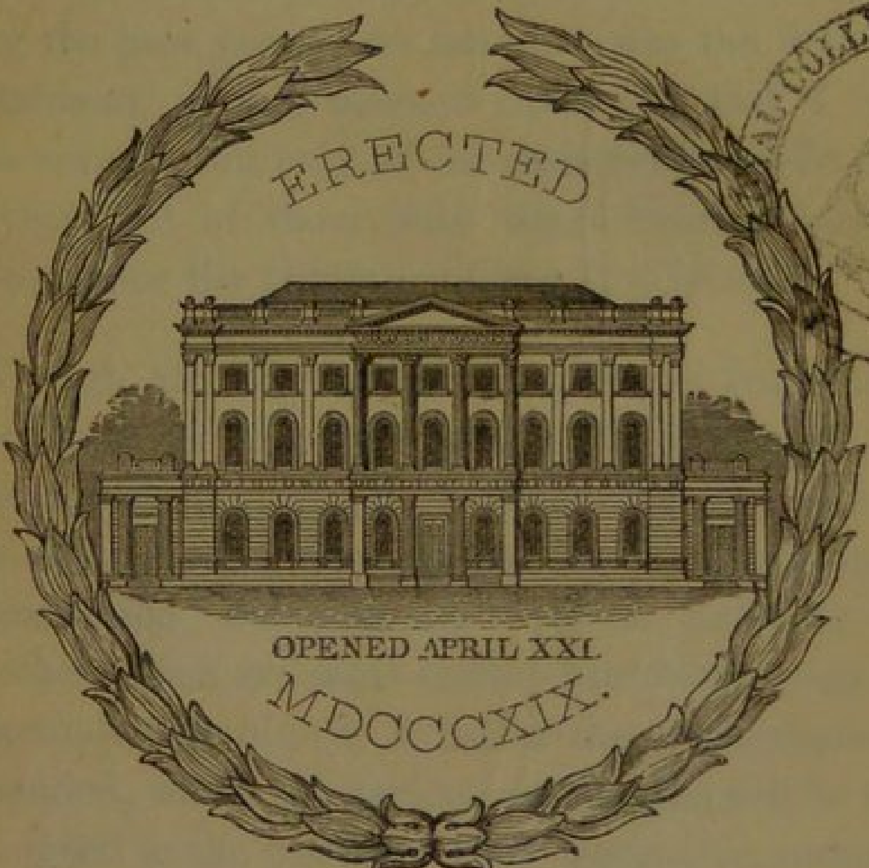

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PREFACE.

Among the Resolutions of the Committee of Management of The London Institution, there is one which requires the Professor of Experimental Philosophy to deliver annually, at the first Soirée for the season, a Lecture on the most remarkable Discoveries in Science during the past year. As last year was the first of my appointment, it was deemed advisable that I should give a *resumé,* not only of the discoveries made during that year, but of those with which Science had been enriched since the Opening of the Institution.

Although any attempt at perspicuous condensation of such a body of matter into a single Lecture, must be deemed futile,—yet it is hoped that the following pages may not altogether disappoint the Proprietors of the Institution, but may serve as an index to those researches which are most worthy attention: more fully to effectuate this object, a list of the original memoirs is appended, where the various discoveries will be found as enounced in the words of their respective authors.

As the Lecture was delivered extempore, I cannot vouch for exact identity of expression in this copy, it having been indited only from memory. I believe, however, that the phraseology will be found to differ no more, than is necessary for the adaptation of oral, to documentary style: perhaps, indeed, it is not sufficiently adapted to the latter; but it appeared to me most in unison with the wishes of the Proprietors, to recal to their minds a Lecture, which at the time of its delivery was explained by illustrations. I felt moreover that I had no right, in preparing for the press at their request a *Lecture* which they had heard, to compile an *Essay* which they had not heard.

Sincerely thanking them for the kind attention and support which I have on this and on all other occasions received at their hands, I take leave to DEDICATE TO THE PROPRIETORS OF THE LONDON INSTITUTION THIS BRIEF NOTICE OF THE RECENT PROGRESS OF SCIENCE.

A LECTURE

ON THE

PROGRESS OF PHYSICAL SCIENCE

SINCE THE OPENING OF

THE LONDON INSTITUTION.

TO extend the range of human knowledge—to place within the grasp of the many, means of its acquisition originally confined to the few—to diffuse a taste for the exercise of the higher faculties with which man is endowed—to transmit, orally and experimentally, the researches of minds, mortal as to their material conjunction, immortal in their effect upon their fellow man—to stand the noblest cenotaphs of genius, the perdurable links which bind it to surviving kindred:—are among the lofty aims of Literary and Scientific Institutions.

If we are not biassed by national vanity in considering London the metropolis of the civilised world—the Institution in which we are at present assembled, THE LONDON INSTITUTION should occupy a high post among the Scientific bodies of Europe.

By means of such Establishments, and through the support given to them by a public which prefers the more enduring and refined gratifications educed by the cultivation of intellect, to the transient, dear-bought pleasures of indolent sensuality;—by means of such endowments and such coadjutors, Science and Literature have lately marched with rapidly-accelerated strides: and it is their progress within the period of Twenty-two years, that I am this evening to sketch.

Vast, indeed is the field; and to lead you step by step over its surface, to cull with you its varied flowers, in the limited time allotted to me is impossible: fortunate I shall be if the omissions I am compelled to make be considered by you as of less importance than the discoveries which I enumerate; but most difficult is it to estimate the comparative importance of results where all are important, all valuable, all conducive to the general weal.

In the year 1815 the *First stone* of this Institution was laid; in the year 1819 the *last:* and in that year an Introductory Discourse was given on the opening of this Theatre by Mr. Brande. From that Discourse we will take date, and examine, as succinctly as our time will permit, the most notable discoveries which have been made since that period; many of which have wrought epochal changes in our knowledge, and will work gradual changes in our political history.

Physical Science treats of Matter, and what I shall to-night term its *Affections*; namely, Attraction, Motion, Heat, Light, Electricity, Magnetism, Chemical-Affinity. When these re-act upon matter they constitute Forces. The present tendency of theory seems to lead to the opinion that all these Affections are resolvable into one, namely, Motion: however, should the theories on these subjects be ultimately so effectually generalised as to become laws, they cannot avoid the necessity for retaining different names for these different Affections; or, as they would then be called, different Modes of Motion. To the Sciences which treat of these various material forces, are given the various titles of Mechanics, Thermotics, Optics, Electricity, Magnetism, Chemistry, Crystallography; and from the united effects of some or other of these, are derived the Composite-Sciences, Geology, Meteorology, and Astronomy. In the very brief sketch which I can on this occasion give you of the recent Progress of Physical Discovery, I shall confine myself to the *Inorganic* Sciences: I shall, therefore, not touch upon Botany, Zoology, nor Anatomy, the normæ of *organised* matter. My apology for this is the absolute necessity of stopping somewhere, of placing some limit to the exhaustless space toward which the mind expands when not restrained within the bounds of conventional classification, "the pales and forts of reason:" thus were I to enter the field of organised being, I should again find myself gradually led over to the scarce-definable boundary which separates Physics from Metaphysics; things apparently remote and distinct become, when curiously pursued, unavoidably connected and inseparate: were our time unlimited, the effort must be made; how much more so when it is dwindled to so short a span as that appropriated to a single lecture.

MECHANICS, the Science of Motion, the first-born of the Sciences, claims our primary attention. Here a most beneficial change has latterly been apparent: laws which, divested of their invariable co-agents, were formerly viewed solely in their abstract relations, have lately been studied by a high order of minds in their state of actual development, and with a view to their practical application. Theory, mathematical-analysis, and experiment, have marched hand in hand, and the labours of Navier and Poncelet have marked an epoch in Mechanical Science, and cleared the grass-grown path originally opened by Coulomb.

Navier in 1826 published a work entitled "*Resumé d'un Cours de Construction*", in which he undertook the discussion of mechanical problems, taking into consideration all their practical conditions. He has there treated at large of the strength of materials in wood and iron, and of the principal and more simple structures formed with these materials. In 1830 appeared the "*Mécanique Industrielle*" of Poncelet, a work which is considered by high authorities to have almost created the Science of Practical Mechanics; and which is not more valuable for the great general interest and importance of its results, than for the simplicity and elegance of the deductions by which they are attained. Poncelet has moreover applied these deductions with great success to water-wheels, the construction of float-boards, and the proper curve to be given to them: by great perseverance he has succeeded in introducing his improvements generally throughout France, where, from the absence of coal-fuel, water-power is of far more value than with us. Undershot and breast-wheels of his construction yield, when compared with those of the old form, one-third more power with the same expense of water. The experiments of Morin, a pupil of Poncelet, made at the cost of the French Government, have given to our knowledge of the effects of friction a high degree of precision and certainty.

In this country Professor Willis has contributed to advance Mechanics by a systematic classification, and has established the mathematical relation of the velocities of the different moving parts of machines. Professor Moseley has recently published a paper, in which he lays down rules for the determination of what he calls "the *Modulus*" of a machine. This term I will endeavor to explain to you. In every machine there are four mechanical elements:—first, the work done by the motive power upon the driving points: secondly, that expended upon the working points, that is those parts of the machine where the original motive power is utilised: thirdly, the work wasted or expended upon the prejudicial resistences, such as friction, aërial-opposition, etc.: and fourthly, that accumulated in the moving elements; as for instance in a fly-wheel, where the power impressed by the machine when in its most advantageous mechanical situation is accumulated, and again evolved when the initial power decreases. Between these four elements there exists a relation, which is always the same for the same machine, and different for different machines; this relation is what Mr. Moseley calls "the *Modulus*", and this relation he determines for simple and compound machines.

I may not, on the present occasion, experimentally elucidate to you the various practical improvements which machines have undergone during the period we are considering, but we need little experiment when a daily survey of the now-familiar arts must force on the mind a conviction of the rapid advance which this Science has recently made, whereby its influence on civilisation is increased to an extent unequalled by many if not by any of the other Sciences. Perhaps the grandest mastery of mind over matter, the greatest result of mechanical power, is evinced in the rail-road locomotive-machines which convey us with such rapidity that, if the notion be correct which considers time to be only a succession of events, we may, compared with our ancestors, be said to live two lives in one; but so unperceived is the onward march of Science, that we marvel not at what a few years back would have been deemed a miracle: the steps by which we advance are so numerous, that we note not the height to which we have mounted; the rock is worn away and we count not the drops of water which have hollowed it.

Another strange mechanical power has been educed by the labours of Mr. Babbage and others, by which the hand is made to do the work of the mind; by which calculations requiring much study, much activity of thought, much strained attention—more perhaps than any single intellect could bring to bear—can be wrought by turning a winch or pressing a treadle. Mr. Babbage has devised and partly constructed two machines for calculating and printing astronomical tables; the first would employ 120 figures, the second 4000: the latter would calculate the numerical value of any algebraic fraction, and, at any executory period previously fixed on, would cease to tabulate that and commence a different one. These machines have never been completed, from the enormous expense attendant upon their construction; enough however has been done to establish the practicability of them, and no doubt can rest on the minds of those who have duly considered the subject, that expense alone is the barrier to attaining by these means any degree of arithmetical perfection.

For performing the more simple calculations of addition, subtraction, multiplication, and division, two instruments, invented I believe by Dr. Roth, have lately been exhibited in this city. They occupy very little space; the one being a circle of about a foot in diameter, the other an oblong of one foot by three inches: they are adapted to our denomination of money, and must form most useful adjuncts to the merchant's counting-house.

In my list of Sciences I have not included *Acoustics*, as this science is so immediately resolvable into Mechanics; all the effects of sound, except those more mysterious ones which take place between the exterior organ of hearing and the sensorium,—having been demonstratively traced to Motion. In this branch of Mechanics much also has been done, and here the name of Savart stands pre-eminent. I would willingly give you a resumé of his labours, the more so as he now lives but in the minds of those who have studied them; but if Sir John Herschel expresses his inability to condense them into twenty close-printed folios, I need say little to make you understand how briefly I must slur them over.

Savart has most perseveringly devoted himself to the study of Sonorous Vibrations, and the communication of them from one body to another. Poisson established a law which gave the relation of notes produced by the transverse and longitudinal vibrations of a rod; Savart found that if two rods be made to touch each other perpendicularly, the longitudinal vibration of the one occasions transverse vibration in the other, and conversely. He further generalised this, and proved that alternations of chords with laminæ, or even of solids with liquids and gases, are affected by longitudinal or transverse vibration, according as their position is parallel or perpendicular to the direction of the initial motion, that if one set be made to vibrate longitudinally, those at right angles to them will suffer transverse vibration, so that the actual direction of all communicated vibration is always parallel.

Another proposition of Savart's is, that the notion of the definite nature of sounds produced by the vibration of the same cord or rod is inaccurate, and that the sounds produced by these may be made to pass one into another by imperceptible gradations. Savart has moreover experimentally traced the forms of the nodal surfaces which divide vibrating masses of air, that is, the surfaces which are at rest while isochronous vibrations take place on either side, and which I may rudely assimilate to the fulcrum of a lever, or to the central point in a balance-beam.

The invention of the *Syren* by Cagniart De la Tour, is another important discovery in the Dynamics of Sound. A musical note is, as you probably know, a succession of vibratory impulses at equal intervals: the pitch of the note is determined solely by the frequency of repetition of the impulses: by knowing then the exact number of impulses in a given time, we may predict the pitch of the note produced by them, and, *vice versá*, by ascertaining the pitch of the note, we may tell at once the number of impulses; a peg in the periphery of a rapidly revolving wheel will thus by the note it utters in striking against a projecting card, give us the number of revolutions of the wheel in a given time. This is one form of the Syren, and was beautifully applied by Mr. Wheatstone in the experiments he instituted to ascertain the velocity of an electric-current.

In giving you this short notice of researches in Acoustics, I am aware I am open to the charge of obscurity: "brevis esse laboro obscurus fio." Researches which extend over a long period, embrace a vast number of facts, and assume in those who study them, a familiar previous acquaintance with their subject,—are incapable of clear and perspicuous abbreviation; and I fear that some subjects of which I shall to-night treat, will lay me open to this charge: with reference to them I must beg you to regard my present Lecture merely as a catalogue raisonnée. There are other discoveries of which, each being capable of clear enunciation in a single proposition, I trust, even in this brief sketch, to give you some efficient notion.

I cannot pass from the subject of Mechanics, without alluding to a loss which this Institution has recently experienced in the death of its Vice-President, Dr. Birkbeck. To many present he was doubtless better known than to myself; but from my short acquaintance with him, I could not but be much impressed with his zeal for the promotion of Science, and the mild benevolence of his character: and it is due to him from you, it is due to him from me, filling the situation here with which your suffrages have honoured me, not to let his memory glide from us unnoticed. Peace to his spirit!

In Chemistry we have recently received vast accessions to our store of knowledge. Faraday has caught the mantle of Davy, and has amplified and adorned it. In treating of the progress of this science, I will begin with that branch which verges upon Mechanics, by recording the memorable step made by Faraday in the Condensation of the Gases. Before the year 1823, it was a matter of doubt whether those elements which we then always and only saw in a gaseous state, did not differ physically from those which retained it only while under the influence of a temporary accession of caloric. Faraday proved this difference to be only in degree: he proved, experimentally and conclusively, that a vast number of what were previously considered permanent gases, could be made to assume the liquid state by reduction of their temperature and mechanical compression. He effected this by eliminating them from solid or liquid compounds in close vessels, kept at a low temperature by artificial frigorific mixtures, and he thus succeeded in liquifying a great number of gases at different degrees of temperature and pressure.

Thilorier proved that by allowing compressed carbonic-acid gas to escape through a small aperture, the excessive cold produced by the abstraction of latent-heat during its sudden expansion, was sufficient to solidify or freeze the carbonic-acid itself; he thus added to the philosophical value of Faraday's discovery, and afforded the chemist a ready means of producing an intense cold; so much so, that it is estimated at 212° below the freezing point of water, or 140° below the freezing point of Mercury. From this practical demonstration, we have every reason to suppose that the remaining aëriform substances which have hitherto resisted a change of molecular state, do so merely from our inability to subject them to a sufficient degree of cold or compression, and, consequently, that the solid, liquid, and gaseous states, are common to all bodies.

We have added to our previous catalogue of Metals six new ones; namely, *Silicium, Zirconium, Thorinum, Glucinum, Vanadium,* and *Lantanum.* A new element, *Bromine,* has also been discovered by M. Balard, of Montpelier. This element so called from its pungent smell, is obtained from sea-water and sea-weeds; it exists at ordinary temperatures as a liquid, specific gravity 2.9 and chemical equivalent 78; metals finely divided, take fire spontaneously in its vapour; it is highly poisonous; and is, in most of its properties, an analogue of chlorine and iodine.

By the labours of Mitscherlich and others, a new relation has been observed between the chemical constitution of bodies and the forms of their crystals; and has given rise to the doctrine of *Isomorphism.* It may be enounced thus:—certain analagous bodies have the power of impressing upon their compounds with the same substances, the same crystalline forms; we may, *è converso,* to a certain extent deduce from identity of crystalline form, analogy in the basic constituents. Thus the crystal sulphate of alumina and potash, is identical in form with that of sulphate of alumina and soda, or sulphate of alumina and ammonia; and hence potash, soda, and ammonia, are said to be *isomorphous.* From having the same crystalline form and angle, isomorphous bodies will crystalise together: thus a crystal of sulphate of potash and alumina will be augmented in size, but unaltered in form, by being placed in a solution of sulphate of ammonia and alumina; again, place it in a solution in which the alumina is replaced by peroxide of iron, it will still augment; and again replace the peroxide of iron by oxide of chrome, and a further augmentation takes place. Thus what I before stated of potash, soda, and ammonia, also holds good of alumina, peroxide of iron, and oxide of chrome; they impress upon analogous compounds, identical forms.

This relation of *Isomorphism* may be extended to a great variety of bodies, but has not the universality of a law; certain bodies being capable of producing two characters of crystal, and thence called *dimorphous,* and others modifying each other's forms by altering the crystalline angles, and thence called *plesiomorphous*. We may with reason hope that a further generalisation will unite under a new bond, all these exceptions; as it is very commonly observable of the progress of science, that relations which at first bear the character of universality, when closely pursued lose it among the variety of exceptions; and that, subsequently, by a more comprehensive generalisation, these are again united as the indispensable links of a wider circling chain.

The doctrine of *Isomerism* forms another prominent feature of recent chemical investigation. It has been discovered that certain substances differing considerably in many of their leading properties, yet possess the same ultimate chemical constitution. Thus the solid substance called *Paraffine* is composed of one equivalent, or one part by weight, of hydrogen, and one equivalent, or six parts by weight, of carbon: this substance is solid, volatile only at high temperatures, and little prone to form combinations. Olefiant gas composed of the same elements in the same proportion; is aëriform at all known temperatures; incapable of solidification; and enters largely into a vast variety of compounds: many other instances exist.

We may possibly at a future period, be able by a more refined analysis to detect some now latent difference in the chemical constitution of isomeric bodies; but until this be the case, we must admit the seeming paradox that bodies identical in constitution may be entirely different in properties, and must refer it to a mysterious state of molecular aggregation.

Organic-Chemistry[a] is marked by the progress of the doctrine of Compound-radicals, the theory of Substitutions of Dumas, and the agricultural discoveries of Liebig. The discovery of Cyanogen by Gay-Lussac, was probably the first inducement to the doctrine of Compound-radicals; a doctrine which is now generally, perhaps too generally, received in Organic Chemistry. As in the case of Cyanogen, a body ob-

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[a] I scarcely need observe that this notice of Organic-Chemistry forms no exception to the rule which I have laid down in page 6; as, notwithstanding its name, Organic-Chemistry as here alluded to is strictly an Inorganic Science.

viously compound discharged in almost all its reactions the functions of an element; so in many other cases it was found that compound bodies in which a great number of elements existed, might be regarded as binary combinations, by considering certain groups of these elements as a compound radical; that is as a simple body when treated of in relation to the more complex substances of which it forms part, and only as non-elementary when referred to its internal constitution.

Undoubtedly by approximating in theory the reactions of inorganic and of organic chemistry, by keeping the mind within the limits of a scientific path, instead of allowing it to wander through a maze of isolated facts, the doctrine of compound-radicals has been of service: but on the other hand, the indefinite variety of changes which may be rung upon the composition of any organic substance by different associations of their primary elements, makes their binary constituents vary as the minds of the authors who treat of them, and depend entirely upon the strength of the analogies presented to each individual mind; from this cause, and from the extreme license which has been taken in theoretic groupings deduced from this doctrine, a serious question arises whether it may not ultimately, unless carefully restricted, produce confusion rather than simplicity, eccentricity rather than regularity.

Dumas has discovered a remarkable class of facts in Organic-Chemistry; namely, that in certain compounds an equivalent of one element may be replaced by an equivalent of another, differing from it entirely in chemical properties, without essentially altering the character of the substance of which it forms a constituent. Thus the hydrogen of certain compounds may be replaced by chlorine, iodine, or bromine, without materially changing the properties of the compound; he has thence promulgated a theory that the elements of bodies are held together by a species of molecular equilibrium, entirely independent of chemical affinity, and that compounds are to be classed according to what he calls *chemical* or *mechanical Types:* the former deduced from their combining properties, the latter from their numerical equivalents. Whatever be the value of his theory, many of the facts observed by Dumas are of great importance; and if not of sufficient generality to originate new views of chemical action, must be regarded as curious exceptions to the received doctrines.

Catalysis, or the chemical action induced by the mere presence of a foreign body, embraces a class of facts which must modify considerably many of our notions of chemical action; thus, oxygen and hydrogen when mixed in a gaseous state, will remain unaltered for an indefinite period; but the introduction to them of a slip of clean platinum will cause more or less rapid combination, without being in itself in any respect altered: on the other hand, oxygenated water, which is a compound of one equivalent of hydrogen plus two of oxygen, will, when under a certain temperature, remain perfectly stable, but touch it with platinum in a state of minute division, and it is instantly decomposed, one equivalent of oxygen being set free: here again the platinum is unaltered, and thus we have synthesis and analysis effected by the mere contact of a foreign body. I am strongly disposed to consider that the facts of Catalysis depend upon voltaic action, to generate which three heterogeneous substances are always necessary: Induced by this belief I made some experiments on the subject, and succeeded in forming a voltaic combination by gaseous-oxygen, gaseous-hydrogen, and platinum; by which a galvanometer was deflected and water decomposed.

The detection of diversity of chemical constitution by what is called *Circular Polarisation of Light*, took place before the opening of this Institution, but its application to Chemistry by M. Biot is of later date, and forms a beautiful instance of the connexion of the different branches of Physical Science, and of the practical value of such connexion. Light, as you know, when polarised appears to be transmitted by undulations in certain planes, and to be incapable of transmission in planes inclined to these at right angles. In ordinary cases of polarisation, each of the colours which compose white light, is polarised in the same plane, but in certain bodies, quartz for instance, the plane of polarisation for each colour is slightly turned round like the grooves in a rifle-barrel; so that the compound light is opened out as a fan: many liquids possess this power, and some during the process of fermentation change the direction in which polarising planes open out: thus with starch while undergoing the saccharine fermentation, the fan appears as it were to close and open again in the opposite direction. Hence this phenomenon of circular polarisation becomes a test of the point which the fermented liquor has reached; and, consequently, of the quantity of sugar formed. As in this, so in innumerable other cases, the most recondite scientific discoveries find, ere long, their application to the arts, and add, not only to the mental advancement, but also to the comforts, the luxuries, and the power of man.

Volta, the antitype of Prometheus, laid in 1800 the foundation-stone of a Science which, during the last twenty-two years, has acquired gigantic dimensions; and which seems likely, at no distant period, to effect a complete revolution in our civil arts. Davy, in his celebrated Bakerian Lecture, generalised the theories of Fabroni and Wollaston as to the relation of chemical and voltaic force; and Faraday, by his great discovery of *Definite Electrolysis*, has gifted ELECTRICITY with a numerical and quantitative precision similar to that which Chemistry derived from the labours of Dalton.

The equivalent chemical action of the Voltaic-pile, developed in his masterly papers, the dates of which extend over a considerable portion of the period we are contemplating, I will endeavor as succinctly as I may to explain to you.

Dalton, as many of you are aware, proved that the constituents of compound chemical substances always bore a definite quantitative relation to each other: thus water, which consists of one part by weight of hydrogen united to eight parts of oxygen, cannot be formed by the same elements in any other than these proportions; you can neither add nor subtract from the normal ratio of the elements, without entirely altering the nature of the compound. Further, if any element be selected as unity, the combining ratios of any other elements will bear an invariable quantitative relation to that and to each other: thus, if hydrogen be chosen as 1, oxygen will be 8, chlorine will be 36; that is, oxygen will unite with hydrogen in the proportion of eight parts by weight to one, while chlorine will unite with hydrogen in the proportion of 36 to 1, or with oxygen in the proportion of 36 to 8. Numbers expressing their combining weights which are thus relative, not absolute, may, by a conventional assent as to the point of unity, be fixed for all chemical reagents; and, when so fixed, it will be found that bodies only unite in those proportions, or in simple multiples of them; these proportions are termed *Equivalents*.

Now a Voltaic battery, which consists generally of alternations of two metals, and a liquid capable of acting chemically on one of them, has the power of producing chemical action in a liquid connected with it by metals upon which this liquid is incapable of acting; in such case the constituents of the liquid will be eliminated at the surfaces of the immersed metals, and at a distance one from the other. For example, if the two platinum terminals of a Voltaic-series be immersed in water, oxygen will be evolved at one and hydrogen at the other terminal, exactly in the proportions in which they form water; while, to the most minute examination, no action is perceptible in the intervening stratum of liquid. It was known before Faraday's time that, while this chemical action was going on in the subjected liquid, a chemical action was going on in the cells of the Voltaic battery, but it was not known that the amount of chemical action in the one bore any constant relation to the amount of action in the other. Faraday proved that it bore a direct equivalent relation: that is, supposing the battery to be formed of zinc and platinum and water, the amount of oxygen which united with the zinc in each cell of the battery, was exactly equal to the amount evolved at the one platinum terminal, while the hydrogen evolved from each platinum plate of the battery, was equal to the hydrogen evolved from the other platinum terminal.

Supposing that instead of water, the battery were charged with hydrochloric-acid, which consists of chlorine and hydrogen, while the terminals were separated by water, then for every 36 parts by weight of chlorine which united with each plate of zinc, 8 parts of oxygen would be evolved from one of the platinum terminals: that is, the weights would be precisely in the same relation which Dalton proved to exist in their chemical combining weights. This may be extended to all liquids capable of being decomposed by the Voltaic force, which Faraday thence called *Electrolytes*:—and as no voltaic effect is produced by liquids incapable of being thus decomposed, it follows that Voltaic action is Chemical action taking place at a distance, or transferred through a chain of media: and that the Daltonian equivalent numbers are the exponents of the amount of voltaic action for corresponding chemical substances.

Let us now pass from this important law to review an epochal discovery connected with this Science, namely, that made by Œrsted of the relation of the electric and magnetic force. Œrsted, in 1820, seized the, till then unknown, link which binds these two Sciences, and proved that Electricity and Magnetism are two forces which act upon each other; not in straight lines, as all other known forces do, but in a rectangular direction: that is, that bodies invested with electricity, or the conduits of an electric-current, tend to place magnets at right angles to them; and, conversely, that magnets tend to place bodies conducting electricity at right angles to them. Thus an electric-current appears to have a magnetic-action, in a direction cutting its own at right angles; or, supposing its section to be a circle, tangential to it; if then we reverse the position, and make the electric current form a series of tangents to an imaginary cylinder, this cylinder should be a magnet. This is effected in practice by coiling a wire as a helix or spiral, and this, when electrified, is to all intents and purposes a magnet. A soft iron core placed within such a helix, has the property of concentrating its power, which would otherwise be somewhat diffuse; and then we can, by connexion or disconnexion with the source of electricity, instantly make or unmake a most powerful magnet.

Now suppose two such helices arranged in the form of a cross, and mobile in their own plane around their point of junction; suppose one of these magnetised by connexion with a voltaic-battery; if a piece of iron be brought near to it the magnetised limb of the cross will of course approach; when it has arrived opposite the iron, let the voltaic connexion be severed as to this limb, and united as to the other, the one will cease to be attracted, and the other will approach in its turn: when it arrives opposite the magnetism may be again transferred; and thus by alternating the voltaic connexion the cross rotates. By a very simple mechanism the rotatory cross may itself effect the union and disruption of voltaic continuity; and thus a mechanical power of facile application is obtained from this novel, invisible, mysterious force. I have this season shewn you a lathe worked by this power, a boat propelled by it, and given you the statistics of its expense. I am far from despairing of its being, within no very distant period, introduced into the Arts as a mechanical agent; and I trust I may, without incurring the charge of vanity, express the pleasure it gives me that my own experiments have somewhat contributed to this result. Probably many now present who have recently witnessed the practical application of Electro-Magnetism to mechanical motion, were also present in this Theatre, when Davy, aided by the extensive and valuable apparatus of Mr. Pepys, here exhibited the first-fruits of his researches in this branch of Science.

The discovery of Œrsted, by which Electricity was made a source of Magnetism, soon led philosophers to seek the converse effect; that is, to educe Electricity from a permanent magnet:—had these experimentalists succeeded in their expectations of making a stationary magnet a source of electric-currents, they would have realised the ancient dreams of perpetual motion, they would have converted statics into dynamics, they would have produced power without expenditure; in other words, they would have become creators. They failed, and Faraday saw their error: he proved that to obtain Electricity from Magnetism it was necessary to superadd to this latter, motion; that magnets while in motion induced electricity in contiguous conductors; and that the direction of such electric-currents was tangential to the polar direction of the magnet; that as Dynamic-electricity may be made the source of Magnetism and motion, so Magnetism conjoined with Motion may be made the source of Electricity. Here originates the Science of Magneto-electricity, the true converse of Electro-magnetism; and thus between Electricity and Magnetism is shewn to exist a reciprocity of force such that, considering either as the primary agent, the other becomes the re-agent; viewing one in the relation of cause, the other is the effect. A corollary from this, leads us to the knowledge that as on this planet there is a constant magnetic direction, so all motion must induce electric-currents; these again induce magnetism, and consequently all conductors of electricity whilst in motion are magnetic: this circumstance formed a fruitful source of error to early experimentalists, and is at present by no means as generally understood as it should be. In the discoveries of Œrsted and Faraday, we have a striking example of the superiority of intuitive perception over formal rules and didactic theories: in each case a connexion was generally suspected and strongly believed; theories without number were propounded, and fallacies authoritatively enforced, failure succeeded failure, until the eagle-flight of genius swooped upon the citadel, which theory had vainly attempted to scale.

In 1821, Seebeck of Berlin found that if two dissimilar metals be soldered together, or in any way brought into close contact, and heated at the point of junction, a current of electricity flowed through the metals, which continued with the increment of temperature, ceased when the temperature was constant, and reversed its direction as the metals cooled: hence sprung the Science of *Thermo-Electricity*, which connected heat with electricity, and proved these, like all other natural forces, to be capable of mutual reaction.

The discoveries in Electricity have been so numerous, and my own belief in their importance is so strong, that I fear occupying an undue portion of your time in the discussion of this subject; still there are so many points, the notice of which presents itself to my mind as indispensable, so many applications which to me appear certain to interweave themselves with our economic-arts;—that I am sure you will hear me enumerate them with patience, and excuse the perhaps tedious enthusiasm of a votary.

In France, M. Becquerel, and, in our own country, Mr. Crosse, have, by the action of slow electrical-currents, realised artificially the beautiful crystalline products of nature; products which the resources of chemistry had failed to yield: through their labours, and those of other experimentalists, much light has been thrown on the formation of mineral veins, a geological theorem which had previously been involved in dense obscurity.

Mr. Wheatstone has, by a most ingenious experiment, succeeded to a certain extent in measuring the velocity of Electricity; which in a copper wire appears to travel at the rate of 288,000 miles per second, a velocity exceeding that of light. In conjunction with other philosophers, Mr. Wheatstone has made much progress in the application of this mysterious power to telegraphic communication; and we are thus enabled to convey our ideas over an indefinite portion of space in all weather, at all periods of day or night, with a rapidity practically instantaneous.

Dr. Ohm, of Nuremberg, has made most valuable contributions to Electrical science, by deducing theoretically and experimentally, formulæ by which the power of any voltaic-circuit can be calculated: his fundamental equation is, that the resulting-force is equal to the sum of the electromotive-forces divided by the sum of the resistances; and this is found to hold good, whether the electromotive-force be theoretically considered as originated by contact or by chemical action. On the moot question of the *source* of Electricity in the Voltaic-pile, I will not now enter, it being purely theoretical; and as it is generally admitted that the quantity or quantitative-action of Electricity is always proportional to the chemical action, all the consequences appear to me to flow equally whether the contact or chemical theory be adopted. By regarding the quantity of electrical, as directly proportional to the efficient chemical action, and by experimentally tracing this principle, I have been fortunate enough to increase the power of the Voltaic-pile more than sixteen times,[a] as compared with any combination previously known.

Last, but not least, not only within the life-time of this Institution, but almost within the short period during which I have had the honour to hold office in it, an application of voltaic-action of incalculable value to this and future generations, has arisen in the *Electrotype* and its derivatives. By this art, sculptures may be copied with the most microscopic accuracy of detail: copied, not in a temporary fragile material, but in the most durable metals, so that instead of the bronze statue or relievo being published in plaster casts the plaster gives its form to innumerable casts of bronze.

By this art, the inferior metals are coated with the superior, and the use of mercury, and consequent injury to health, is avoided. By this art, engravings are indefinitely multiplied; and, by an application of this art which is this evening brought before you for the first time,—Paintings may be stamped upon copper; oil-colour drawings may be made to form the matrix whence solid copper moulds can be taken. To the beautiful copper intaglios which I now present to you, the Patentee has given the name of *Electrotints*. To form them, the design is originally drawn in black on a whitish metal, and, this being coated with plumbago to make it a conductor of electricity, the so-prepared plate is made the cathode[b] of a voltaic-circuit in a solution of sulphate of copper: from this solution the copper is precipitated upon the painting by the electrolytic-action; and, when the solid sheet of copper thus formed is stripped off, all

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[a] $16\frac{1}{2}$ according to Jacobi's measurement.

[b] Negative-pole.

the details of the design are faithfully represented thereon in permanent intaglio.

Had it been prophesied at the close of the last century that, by the aid of an invisible, intangible, imponderable, agent, man would, in the space of forty years, be able to resolve into their elements the most refractory compounds, to fuse the most intractable metals, to propel the vessel or the carriage, to imitate without manual labour the most costly fabrics, and, in the communication of ideas, almost to annihilate time and space;—the prophet, Cassandra-like, would have been laughed to scorn.

In Thermotics, or the Science of Heat, there are two branches of research to which I shall call your attention: the one those of Dulong and Petit, on the relation of the specific heat of bodies to their chemical-equivalents; the other those of Melloni and Forbes, on the physical laws of Radiant-heat. The former researches have proved, that the specific heats of very many elementary bodies give, when multiplied by their chemical-equivalents, a constant quantity. (The specific heat of bodies, is that relative proportion which equal weights require to raise or lower them from a given temperature to another given temperature.) Let us take for instance lead and zinc: the equivalent or combining weight of lead on the hydrogen scale is 104, and of zinc 32: if we take equal weights of these two bodies at a temperature of 50° Fahrenheit, we shall find that in round numbers about three times as much heat will be necessary to raise zinc to the temperature of 60°, as it will to raise the lead to it; consequently, if we take three times as much in weight of lead as of zinc, these weights will require equal quantities of heat to raise them to the same temperature; but the combining-weights are nearly 3 to 1; and therefore, if this relation hold good with other bodies, it will appear that the combining-weights of bodies are those weights which require equal accessions or abstractions of heat to raise or lower their temperature equally; or, in other words, that the specific heat of bodies is inversely as their combining-weight.

Neumann and Avogadro have extended this relation between the specific heat and the combining-weights, to many compound chemicals; unfortunately, the exceptions to this rule are as numerous as the cases which fall within it, but the principle is so simple and beautiful, that more refined investigation and a more profound knowledge of the law of equivalents, may extend it to universality.

Before the researches of Melloni and Forbes, the analogies of the phenomena of Radiant Heat and Light were very imperfectly known, and confined to a few general resemblances. These experimentalists have extended the analogy to all the functions of these two material affections, and all that was before known of Light is now, under differing circumstances, predicable of Radiant-heat. Thus Radiant-heat is capable of reflexion, absorption, refraction, double-refraction, polarisation: it also produces effects in all but sensation analogous to those of colour.

The experiments which have demonstrated these points, afford a beautiful instance of the assistance which the progress of one branch of physical science renders to that of another. The discoveries of Œrsted and Seebeck led to the construction of an instrument for measuring temperature, incomparably more delicate than any previously known. To distinguish it from the ordinary thermometer, this instrument is called the *Thermo-Multiplier*. It consists of a series of small bars of bismuth and antimony, forming one zig-zag chain of alternations arranged parallel to each other, in the shape of a cylinder or prism; so that the points of junction, which are soldered, shall be all exposed at the bases of the cylinder: the two extremities of this series are united to a Galvanometer, that is, a flat coil of wire surrounding a freely-suspended magnetic needle, the direction of which is parallel to the convolutions of the wire. When Radiant-heat impinges upon the soldered ends of the Multiplier, a thermo-electric-current is induced in each pair; and, as all these currents tend to circulate in the same direction, the energy of the whole is increased as the sum of their added forces: this current traversing the helix of the Galvanometer deflects the needle from parallelism by virtue of the electro-magnetic tangential force; and the degree of this deflexion serves as the index of the temperature.

Bodies examined by these means, shew a remarkable difference between their transcalence, or power of transmitting heat and their transparency: thus perfectly transparent alum, arrests more heat than quartz so dark coloured as to be opaque; and alum coupled with green glass Melloni found was capable of transmitting a beam of brilliant light; while, with the most delicate thermoscope, it gave no indications of transmitted heat: on the other hand, rock-salt, the most transcalescent body known, may be covered with soot until perfectly opaque, and yet be found capable of transmitting a considerable quantity of heat. Radiant-heat when transmitted through a prism of rock-salt, is found to be unequally refracted, as is the case with light; and the rays of heat thus elongated into what is for the sake of analogy called a spectrum, are found to possess similar properties to the primary or coloured rays of light: thus rock-salt is to heat, what colourless glass is to light; it transmits heat of all degrees of refrangibility: alum is to heat as red glass to light, it transmits the least, and stops the most refrangible rays; and rock-salt covered with soot represents blue glass, transmitting the most, and stopping the least refrangible rays.

Certain bodies again reflect heat of different refrangibility: thus paper, snow, and white lime, although perfectly white, that is, reflecting light of all degrees of refrangibility, reflect heat only of certain degrees, while metals, which are coloured bodies, that is, bodies which reflect light only of certain degrees of refrangibility, reflect heat of all degrees. Radiant-heat incident upon substances which doubly refract light, is doubly refracted; and the emergent rays are polarised in planes at right angles to each other, as is the case with light. Thus the phenomena of light are imitated closely by those of Radiant-heat; and the same theory which is considered most plausibly to account for the phenomena of the one, will necessarily be applied to the other agent.

The theory at present considered most explanatory of the effects of these two material affections, is, as you are probably aware, what is called the *Undulatory*: namely, that which supposes all space and the pores of all bodies to be filled with a medium of extreme tenuity called *Ether;* and that by vibrations or waves propagated through this medium the phenomena are produced. Agreeing as I do in the value and general application of the Undulatory-theory, it has always seemed to me that the assumption of a specific luminiferous ether, differing from ordinary matter, is gratuitous and difficult of conception.

It appears to me that heat and light may be considered as affections; or, according to the Undulatory-theory, vibrations of matter itself and not of a distinct etherial fluid permeating it: these vibrations would be propagated, just as sound is propagated by vibrations of wood or as waves by water. To my mind, all the consequences of the Undulatory-theory flow as easily from this, as from the hypothesis of a specific ether; to suppose which, namely, to suppose a fluid *sui generis*, and of extreme tenuity penetrating solid bodies, we must assume first, the existence of the fluid itself; secondly, that bodies are without exception porous; thirdly, that these pores communicate; fourthly, that matter is limited in expansibility. None of these difficulties apply to the modification of this theory which I venture to propose; and no other difficulty applies to it which does not equally apply to the received hypothesis. With regard to the planetary spaces, the diminishing periods of comets is a strong argument for the existence of an universally-diffused matter: this has the function of resistance, and there appears to be no reason to divest it of the functions common to all matter, or specifically to appropriate it to certain affections. Again, the phenomena of transparency and opacity, are, to my mind, more easily explicable by the former than by the latter theory; as resulting from a difference in the molecular arrangement of the matter affected. In regard to the effects of double-refraction and polarisation, the molecular structure gives at once a reason for the effects upon the one theory, while upon the other we must, in addition to previous assumptions, further assume a different elasticity of the ether in different directions within the doubly-refracting medium. The same theory is applicable to Electricity and Magnetism; my own experiments on the influence of the elastic intermedium on the voltaic-arc, and those of Faraday on electrical-induction, furnish strong arguments in support of it. My inclination would lead me to detain you on this subject much longer than my judgment deems advisable: I therefore content myself with offering it to your consideration, and, should my avocations permit, I may at a future period more fully develope it. I submit these views to you with diffidence, as more experienced minds may find them defective; but their truth presses so strongly upon my own mind, that I cannot resist the temptation of suggesting them.

The close analogy of Heat and Light, leads us naturally from the consideration of the former to that of the latter agent: and here I shall not attempt to trace to you the progress which has been made in the application of the Undulatory-theory of Light: it is too much a matter of detail; there are no salient points; or rather, perhaps, there are too many to permit me to touch upon them. Neither shall I dwell upon the beautiful recent applications of artificial light, as the Bude and Hydroxygen lights, the Polariscope, etc., etc., but confine myself to a short exposé of the most remarkable discovery of modern times—the art of *Photography*.

Certain chemical compounds, among which stand pre-eminent the salts of silver, have the property of suffering decomposition when exposed to light. If, for instance, recently formed chloride of silver be submitted to luminous rays, a partial decomposition ensues; the chlorine is separated and expelled by the action of light, and the silver is precipitated: by this decomposition the colour of the substance changes from white to blue. If now paper be impregnated with chloride of silver, which can be done by a simple chemical process, then partially covered with an opaque substance, a leaf for example, and exposed to a strong light, the chloride will be decomposed in all those parts of the paper where the light is *not* intercepted, and we shall have, by the action of light, a white image of the leaf on a purple ground: if similar paper be placed in the focus of a lens in a camera-obscura, the objects there depicted will decompose the chloride, just in the proportion in which they reflect light; and thus, as the most luminous parts of the image will most darken the chloride we shall have a picture of the objects with reversed lights and shadows. The picture thus produced would not be permanent, as subsequent exposure would darken the light portion of the picture: to fix it we must immerse the paper in a solution which has the property of dissolving chloride of silver, but not metallic silver; iodide of potassium will effect this, and the paper being washed and dried will then preserve a permanent image of the depicted objects. This was the first and simple process of Mr. Talbot; but it is defective in many points. First, it is not sufficiently sensitive, requiring a strong light and a long time to produce an image: secondly, the lights and shadows are reversed: and thirdly, the coarse structure of the finest paper does not admit of the delicate traces of objects being distinctly impressed. In the photographs of M. Daguerre, with which you are all familiar, the above defects are remedied. These photographs are produced by holding a plate of highly-polished silver over iodine; a thin film of iodide of silver is thus formed on the surface of the metal, and when these iodized plates are exposed in the camera, a chemical alteration takes place, the portions of the plate on which the light has impinged, part with some of the iodine, or are otherwise changed—for the theory is somewhat doubtful—so as to be capable of ready amalgamation. When, therefore, the plate is placed over the vapour of heated mercury, the mercury attaches itself to the portions affected by light, and gives them a white frosted appearance; the intermediate tints are less affected, and those parts where no light has fallen, by retaining their original polish, appear dark: the iodide is then washed off by hyposulphite of soda which has the property of dissolving it, and there remains a picture in which the lights and shadows are as in nature, and the molecular uniformity of the metallic surface enables the most microscopic details to be depicted with perfect accuracy: by using chloride of iodine or bromide of iodine, instead of iodine, the equilibrium of chemical forces is rendered still more unstable; so that images may be taken in an indefinitely short period; a period practically instantaneous. I have myself seen one of these Photographs executed in France, in which people are represented as in the act of running and carriages moving.

While Daguerre's process has been thus perfected, Mr. Talbot has much improved the photographic process on paper; and by his new method which he calls *Calotype*, portraits may be taken, which, if they have not the minute perfection of Daguerréotypes, have yet many practical advantages from the nature of the material used.

By applying dilute nitric-acid to the Daguerréotype-plate, the silver portions are eroded more than the mercurialised; and thus an *Etching* is obtained from which prints may be taken. Dr. Berres has thus produced some very good impressions. I have employed Voltaic-Electricity to effect the same purpose; and it appears to me to have many advantages. The Daguerréotype is made the anode or positive-pole of a voltaic-combination, in a solution which will not of itself attack either silver or mercury, the electrolytic-action of the battery evolves an element which attacks unequally these two metals, and produces an exact etching of the original design, a design thus drawn by Light and engraved by Electricity.

It would be vain to attempt specifically to predict what may be the effect of Photography on future generations. A process by which the most transient actions are rendered permanent, by which facts write their own annals in a language that can never become obsolete, forming documents which prove themselves,—must interweave itself not only with Science, but with history and legislature:

"Solem quis dicere falsum audeat?"

The student who in his closet successfully interrogates Nature, not only gives to man new physical knowledge, but works an indelible change in his moral destinies.

Light, Heat, Electricity, Magnetism, Motion, and Chemical-affinity, are all convertible material affections; assuming either as the cause, one of the others will be the effect; thus heat may be said to produce electricity, electricity to produce heat; magnetism to produce electricity, electricity magnetism: and so of the rest. Cause and effect, therefore, in their abstract relation to these forces, are words solely of convenience: we are totally unacquainted with the ultimate generating power of each and all of them, and probably shall ever remain so; we can only ascertain the normæ of their action: we must humbly refer their causation to one omnipresent influence, and content ourselves with studying their effects and developing by experiment their mutual relations.

The forces above-mentioned in their varied natural action upon the surface of this planet, alter continually the nature of its external crust, and this alteration constitutes the Science of Geology: by it we read the past changes of the Earth and can form some judgment of its future ones.

It was supposed during the first periods of geological investigation, that the structural changes of the earth's crust had resulted from certain sudden violent cataclysms; produced, according to the Plutonian theory, by earthquakes, volcanoes, and other igneous agency; or, according to the Neptunian by epochal deluges. The immense scale on which Nature has marked her ancient operations, seemed to negative the possibility of their having been effected by the puny actions of modern date. Although history and even tradition recorded —with the exception of the one universal deluge—no epochal changes at all equivalent to those stamped upon the face of the globe, yet philosophers by an apparently necessary inference, were led to assume violent causes to account for violent effects. The promulgators of these theories felt themselves bound by a period of time limited by tradition: trammels which subsequent geologists, among whom Lyell stands preeminent, have thrown off; and, giving Nature an indefinite time for her operations, they have gone far to prove that all the past changes in the earth's structure are referable to causes now in operation; and that those changes have formerly proceeded with no greater rapidity than Nature now exhibits in her normal state. The length of time required for this theory is not by any means an hypothetic assumption; it is a deduction from well-ascertained premises; premises founded upon a series of careful inductions from observed facts. Those who have carefully studied the subject, cannot refuse assent to the proposition, either that a time immeasurably longer than that assigned by tradition must be extended to the existence of the globe, or that all past events have succeeded each other with a rapidity indefinitely exceeding that which marks the succession of present events. It may seem at first paradoxical, but is strictly true, that whichever of these hypotheses be taken, the same conclusions are deducible: if time be not a succession of events, it is only known to man as marked by events. To simplify a disquisition which borders on metaphysics, I will give an example which may render my views intelligible. Supposing two Islands, A and B, inhabited by two families, and having not the slightest connection with each other or the rest of mankind. Suppose that, as referred to our normal chronology, all events pass in the one with far *increased* rapidity, and in the other with *decreased;* for instance, that what takes place with us in an hour, takes place in Island A in a minute, and in B in sixty hours: the duration of men's life in A would be 1 year and 2 months, in B it would be 4200 years; but the man who lived 14 months, would do as many acts as he who lived 4200 years; his blood would pulse, his thoughts would succeed each other 3600 times more rapidly, he would have the same number of days and nights, of seed-times and harvests: how then could he of A be aware that he lived only $\frac{1}{3600}$ the life of him of B; or would there be any difference, except by reference to a standard of which both are ignorant.[a]

The most simple induction, therefore, as to the duration of past time, is to measure the succession of past events by reference to that of present events. This is what modern Geologists have done, and upon these premises is the modern theory erected.

[a] This instance was not given in my oral Lecture. I have inserted it, as my meaning might otherwise be deemed obscure.

In assenting generally to the theory of Lyell, I would be considered as doing so with some reservation. I am far from thinking that the changes of Nature have always occurred with precise regularity; on the contrary, I am inclined to think that there have been periods at which Nature has undergone changes far beyond her normal ones; while there have been others at which she has been more than usually stationary. Etna bursts not forth every day, nor are her eruptions of equal grandeur; and if in our own time Nature acts not with perfect uniformity, we have no right to assume that she has done so in times past: still in the long lapse of ages these variations are scarce notable; like the waves on the sea-surface, they are altogether lost in perspective.

A new agent has been recently discussed as having concurred and as now concurring to produce various geological changes: namely the action of Glaciers. From an examination of Alpine tracts, where, from an increase of temperature, the glaciers have receded, it has been found that peculiar marks called *Glacial-scratches,* remain; marks which are made by the shifting of vast masses of ice, and which no other known natural force can effect. In other places are found blocks of stone and gravel in connexion with polished and striated rocks, which have resulted from similar glacial action; in others moraines, or terraces on the flanks of valleys formed of detritus of blocks and pebbles, which by their polish and position afford strong evidence of having been there deposited by the melting of the ice. These formations differ from stratified-gravel produced by ordinary aqueous deposition; as here the ingredients are smaller, and the finest portions are at the top, while in glacier-detritus large and small blocks are intermixed, and the superposition depends more upon the shape than upon the size of the masses.

Similar appearances to these have been observed at far distances from the Alps, in various parts of the northern and temperate regions of the earth; and the conclusion is immediate, that they must have been produced by similar causes.

The observation of these remarkable facts, most of which are due to Professor Agassiz, have opened a new field of geological enquiry; they introduce a new agent previously undreamed of; and, taken in connection with previous observations, they prove that considerable alterations of temperature have marked the history of the earth's surface.

From the study of our own abode, from the Science which examines and records its changes, let us pass to that which investigates the laws of surrounding planets, which extends the views of man to other spheres of existence, those "multiplying masses of increased and still increasing light;" let us consider the progress of the Science of ASTRONOMY.

In 1830 Savary calculated the orbit of a double-star, one of those distant luminaries which were first observed by Sir William Herschel, and which prove that the law of gravitation holds good in other systems than our own. Savary found that the Stars of ξ *Ursæ* described an elliptic orbit the period of which was 58¼ of our years. In 1832 Encke calculated the orbit of 70 *Ophiuchi* at 74 years, and since that date the orbits of very many of these luminaries have been determined by our celebrated countryman Sir John Herschel and others: the periods of revolution vary for different stars from 1200 to 40 years.

The recent improvements in the construction of telescopes by Lord Oxmantown, promise to add considerably to optical power and astronomical knowledge; but as it would be vain for me to attempt to describe these and to abstract other valuable recent contributions to this Science, I will limit myself to the mention of one great discovery, which is now fresh in men's minds as the last epoch in the annals of Astronomy: I allude to the *Parallax of the Fixed-Stars.* Parallax is the apparent change of position in an immovable body, resulting from real change of position in a moving one, from which the former is viewed: thus the apparent motion of houses or trees when seen from a carriage-window is a familiar instance of parallax. It is obvious, that the more distant the object the smaller is the apparent change of position or parallax: in rail-road travelling, for instance, we scarcely dare to look upon the adjoining road from the giddiness induced by the velocity with which it appears to pass; while objects at some miles distance appear stationary. It is by means of parallax, that the distance of the celestial bodies from the earth is estimated:—thus two observers at different points of the earth's surface would refer the position of the sun or moon seen at the same time, to different points of space;—from the distance between these apparent positions, may be calculated the distance of the object from the observers; and it will be easily understood from the instance above given, that this parallax will be less as the distance of the object is greater. The Sun has a parallax cognisable by our astronomical instruments, when regarded at the same time from opposite extremities of the earth's diameter; or, what is the same thing, when regarded by the same observer at the distance of twelve hours, the difference of time being allowed for:—for from the revolution of the globe round its axis, he will in twelve hours be at points distant from each other by a little more than the earth's diameter; the angle deduced from this mode of measurement is called Diurnal-parallax. Now the fixed-stars are so distant, that they show no symptom of diurnal-parallax; but fortunately we have much wider ground whence to measure their parallax; as they are *dehors* our System, we can regard them, not only from the extremities of the earth's diameter, but from the extremities of the diameter of the earth's orbit, or the circle she makes in her yearly revolution round the sun: having then by the diurnal parallax of the sun ascertained the length of the diameter of this orbit, which is 190 millions of miles, we get, by observing at periods six months apart, 190,000,000 of miles as the base of our angle; and thus obtain what is called Annual-parallax. Notwithstanding the immense vantage-ground thus acquired, so enormous is the distance of the fixed-stars from us, that observers have until the last few years failed in detecting any measurable parallax. Recently, however, three eminent Astronomers—Bessel of Königsberg, Struve of St. Petersburg, and Henderson of Edinburgh, have simultaneously detected what they conceive to be parallaxes of fixed-stars. Unfortunately the observations of these philosophers have been directed to different stars, and therefore they do not corroborate each other; the researches of Bessel, however, appear to have been subjected to such crucial tests, that the most experienced astronomers assent to the truth of his discovery.

The star on which he has worked, 61 *Cygni*, gives a parallax from which its distance from us is calculated at 670,000 times that of the sun, or 63,650,000,000,000 miles! We can form no conception of this distance; and, however we may assist the mind by comparative admeasurements, we must fail to grasp the immensity of the space thus estimated. Light travels from the Sun to the Earth in eight minutes and a quarter, or at the rate of 192,000 miles per second; and, supposing light to travel with the same velocity from this star, it would be upwards of ten years reaching us: thus when we gaze upon that star we view it as it existed ten years back, and could we magnify it so as to detect changes upon its surface we should view as passing events those which had become matter of history to its inhabitants. Supposing again we take a photographic image of this star, we thus produce a physical change in ponderable matter, and retain a permanent stamp of that which took place ten years back, and which now records itself by the fleeting agency of light. The mind, however it may delight to indulge in curious speculations of this nature, cannot pursue them far without being led beyond its limited powers, and falls "intoxicated with eternity!"

Such are some of the prominent discoveries which have marked the period embraced by the title of my Lecture. While we admire the geometric ratio in which knowledge has advanced, we cannot but be delighted to note the effect of this advance upon the human mind: the sluggish indifference to receive Scientific truths, is decreasing inversely with the march of Science; and the term novelty is no longer one of scorn. If there be a fault in the present tendency of opinion, it is that the reaction from the dogged obstinacy of past time, hurries the judgment and leads men to build large expectations on insufficient data. This is in some degree evidenced in the patent-enrollments; the immense increase of which, and the trifling nature of many of their subjects, not only shews a want of due caution in the speculators, but is of some injury to the cause of Science by shutting up the paths to further improvements. These however are drawbacks of little import, they are evils which cure themselves; time soon separates the wheat from the chaff. The discoveries which we have this Evening considered, are, in my belief, *permanent* additions to our knowledge; whatever further changes may be wrought in nomenclature or systematic arrangement, their facts and natural relations must endure, they are the ever-flowing rivers which swell the ocean: minor inductions, which time has not permitted us to notice, are the brooks which feed these rivers: and the Ocean of Science thus rapidly increasing never overflows, for the capacity for its reception increases with its increase.

Many of you, I trust all of you, may live to see another twenty-two years, to view the varied accessions which that period will bring to our knowledge of Physical Science; and with those accessions to behold a higher pitch of civilisation, a nobler stamp impressed upon man. An acute thinker of the present day has the following remarkable passage "It is thus every where that foolish rumour babbles, not of what was done, but of what was misdone or undone, and foolish History,—(ever more or less the written epitomised synopsis of Rumour)—knows so little that were not as well unknown." Thus writes Carlyle; and true it is that not the Cæsars, the Alexanders, the Napoleons, have made men what they are, but the Galileos, the Bacons, the Newtons, the Voltas.

Why is England a great nation? Is it because her sons are brave? No, for so are the savage denizens of Polynesia: She is great because their bravery is fortified by discipline, and discipline is the offshoot of Science. Why is England a great nation? She is great because she excels in Agriculture, in Manufactures, in Commerce. What is Agriculture without Chemistry? What Manufactures without Mechanics? What Commerce without Navigation? What Navigation without Astronomy?

Dynasties change : republics, by giving scope to the selfishness of the ambitious, lead to monarchy, monarchy to tyranny, tyranny to anarchy, and anarchy again galls the kibe of republicanism; but Science has no selfish despot whose "vaulting ambition doth o'erleap its selle;" her votaries fail not, her steps are certain, her progress ever advancing, her retrocession impossible : her seeds once sown, germinate so quickly, strike root so deeply, that they cannot be uptorn.

Institutions such as this, are among the plants which spring from these seeds : and though, like all material fabrics, they may crumble, may decay, and ultimately " leave not a rack behind", yet their far-spread influence upon generations yet unborn, upon future races of high thinking men, will endure coeval with the duration of our planet.

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