ELECTRO-MAGNETISM.

HISTORY

OF

DAVENPORT'S INVENTION

OF THE

APPLICATION OF ELECTRO-MAGNETISM

TO MACHINERY;

WITH REMARKS ON THE SAME FROM THE AMERICAN JOURNAL OF SCIENCE AND ARTS,

BY PROFESSOR SILLIMAN.

ALSO,

EXTRACTS FROM OTHER PUBLIC JOURNALS,

AND

INFORMATION ON ELECTRICITY, GALVANISM, ELECTRO-MAGNETISM, &c.

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INTRODUCTION.

THE present compilation has been prepared in compliance with the very frequently expressed wish of many inquirers for information on the subject of Electro-Magnetism, particularly with reference to the recent important discovery of Mr. DAVENPORT, of the practicability of the application of this power to machinery. The history of his invention has been prepared by a friend and associate of Mr. Davenport and under his inspection, and will be found to contain the most important facts relative to the rise and progress of this interesting discovery. The remarks of Professor SILLIMAN on the subject, from the *American Journal of Science and Arts*, and the opinions of many editors of our public Journals, follow the narrative.

As Electricity and Magnetism are comparatively modern sciences, and that of Electro-Magnetism is of very recent origin, we have made copious extracts from the able treatise of Mrs. Somerville, "on the connexion of the Physical Sciences," for the information of those who have not time or inclination for researches in more elaborate works.

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HISTORY OF DAVENPORT'S INVENTION.

In 1830 Professor Henry, now of Princeton College, New-Jersey, but then residing at Albany, produced the first electro-magnet manufactured in the United States. His description of its construction and power, which was published in the scientific Journals at the time, excited much curiosity in their readers; the great mass of the people, however, had little or no knowledge of these facts.

The Penfield iron works at Crown Point, on Lake Champlain, were then in operation, but yielding a poor return for the labour bestowed on them, in consequence of what is termed the leanness of the ore. A gentleman desirous of discovering some improved method of working such magnetic ores, (or load stone) on account of the superior qualities of the iron some of them yield, held a consultation with Professor Henry of Albany, and Professor Eaton of Troy, on the subject. This gentleman finally invented a machine principally composed of a wooden cylinder, in which was inserted several hundred points, or teeth, of magnetised steel. These revolved through a mass of pulverized ore, from which they extracted the particles of iron. After these magnetic points left the ore, they passed through a brush which removed the iron adhering to them. This invention was found very useful to many, especially the proprietors of the Penfield works.

Mr. Thomas Davenport, who was then residing in Brandon, Rutland County, Vermont, about twenty miles from Crown Point, and pursuing the occupation of a Blacksmith, went to the Penfield works in 1833, for the purpose of purchasing iron.

It is proper here to remark that Mr. Davenport was at this time somewhat familiar with the compass, and the ordinary tedious process of producing magnetism in steel by friction, but had not even heard of Electro-Magnetism.

On witnessing the operation of the machine before mentioned, he very naturally inquired how they charged so many magnets? He was answered on a galvanic *battery*, pointing to an electro-magnet. The exhibitor also showed the battery which he called the *cups*. Mr. Davenport being thus erroneously instructed, continued to call the magnet a *battery*, and the battery the *cups*, and finally obtained his rotary motion before he was acquainted with the correct names of the articles he was using. But to resume the thread of our narrative. When Mr. Davenport was shown the power of this small electro-magnet, (weighing about four pounds, and which had been made by Professor Henry,) he was so struck with its novelty, and convinced of the important results it might be made to produce, that he immediately demanded the price of the apparatus, and purchased it instead of the iron for which he had journeyed to the place.

On reaching home with his magnet and battery, he exhibited the same to his neighbours, and confidently told them that from this power he could combine sufficient energy to move the largest boats. His declaration was received with general incredulity and ridicule.

He was not discouraged or disappointed by the reception he met with. He thought and reasoned for himself; and relinquishing his trade, devoted his undivided attention to the object in view. After trying hundreds of experiments, and devoting several months to an intensity of reflection, which would have brought many others to a lunatic asylum, he finally in July, 1834, accomplished the arduous task of bringing the invisible and mysterious power of magnetism into subjection. A power which, "steady as the needle to the pole," had been before thought the most unyielding of all others; forming an arrangement by which this very polarity, this steadiness of purpose, is made to produce a rotary motion.

Mr. Davenport, in common with all others who had laboured to attain the same object, was governed by the correct opinion; that when a rotary motion should be obtained, the victory would be achieved. That the scientific and mechanical principle being found, an enlargement, on increased number of parts, would produce any desirable amount of power.

Although these opinions admit of no controversy; for they are based on mathematics, and are daily illustrated in all the varieties of machinery, yet, owing to the novelty of the power, its invisible and silent operation, the minds of the most who at first examined it were so overwhelmed with the achievement of what they had so long considered impossible, that they feared to rely on the best settled principles of matter and motion; and hesitated to embark in endeavours to improve and introduce the invention.

It may be well here to remark that few perhaps, except inventors themselves, are aware of the labour and thought necessary to improve and perfect an important invention, after it has been first produced. The most who examine a piece of simplified and perfected machinery seem to imagine that it was struck out by a single thought of the inventor; such, however, is seldom, if ever, the case.

Although Mr. Davenport had discovered the principle, and formed an arrangement which produced a rotating motion by repeated changes of magnetic poles, he was aware that his machine, in common with most other first inventions, admitted of, and even required, several improvements before it could be advantageously brought into public use. It was not only necessary that funds should be procured, but also, that other minds should be brought to act with his, in accomplishing so desirable an end. Here Mr. Davenport met with the greatest difficulties he had yet encountered. He had produced the invention; his mind required rest, and he desired assistance to improve. He found it easier to operate with electricity than mind; easier to magnetize iron than men; and much easier to obtain compliments than money.

His first machine performed only about two revolutions

per minute; and was not of course very promising to those who looked no farther than to what was immediately before their eyes. But he succeeded in persuading an individual of his neighbourhood to engage with him in improvements, &c. by promising one half of the avails to be realized. This friend, however, soon abandoned the enterprise as visionary, and kindly told Mr. Davenport that he was perfectly welcome to what had been done.

He next made application to a gentleman of wealth, promising all the avails, except one or two thousand dollars, if he would assist him in perfecting and bringing the invention into public use. This gentleman had such a dread of the ridicule which would be heaped upon him in case of failure, that he insisted the arrangement, if any was made, should be kept an inviolable secret. Mr. Davenport conscious of the integrity of his motives, and confident in the final triumph of his exertions, refused the terms.

In December, 1834, Mr. Davenport took his machine to Middlebury College, Vermont, and exhibited it in that institution. Himself and the machine were treated with kind attention. Professor Turner in a particular manner expressed his confidence in its applicability as a motive power, and advised Mr. Davenport to persevere. This first encouragement, from a gentleman of high natural, as well as acquired talents, was very gratefully received by Mr. Davenport.

On his return from Middlebury he succeeded with much difficulty in making an arrangement with another individual to aid in bringing forward the discovery. This friend, who was also a mechanic, persevered for some months, and was finally obliged to relinquish his exertions for want of the necessary funds; retaining, however, his entire confidence in the principle. An amicable settlement was made between the parties, and Mr. Davenport was again left to seek anew for assistance. During this time the machine had been so much improved as to make about thirty revolutions per minute.

In June, 1835, Mr. Davenport brought his machine to

Troy, and exhibited it at the Rensselaer Institute. From thence he proceeded to Princeton, New-Jersey, and submitted it to the examination of Professor Henry, where he first learned that Professor Henry had procured a vibratory motion from magnets. He next visited Philadelphia, and exhibited his machine to Professors Bache, Hamilton, and others, at the Franklin Institute. Professors Henry and Bache both gave Mr. Davenport flattering certificates as to the originality and importance of his invention.

He then proceeded to Washington, and deposited his specification in the patent office.

After his return from Washington he went to Springfield, Massachusetts, where, with the assistance of some mechanics, he built a small circular rail-way, on which he placed an Electro-Magnetic Engine. With this apparatus he proceeded to Boston in December, 1835, and exhibited the same two weeks at the Marlboro' Hotel. Notwithstanding it was favourably noticed in some of the Boston Papers, he met with no offers of assistance towards a farther prosecution of his plan. During the whole period Mr. Davenport employed his time, when not travelling, in experiments on this science.

In the summer of 1836 he visited Saratoga Springs, where he exhibited his machine two weeks. Here he became acquainted with Mr. Ransom Cook, a mechanic of that place; who being the owner of a fine shop, with excellent machinery, moved by steam power, more readily appreciated the value of Mr. Davenport's invention, than could have been expected from many others. Struck with its value and importance on his first examination, Mr. Cook offered, from benevolent motives alone, to assist Mr. Davenport in bringing it into public use.

As the patent had not yet been obtained, Messrs. Davenport and Cook commenced building a model to deposite in the patent office. As the work progressed, Mr. Cook made an important alteration in the arrangement of the machine, and became more and more enamoured with the invention. Every well established fact, and every new discovery in this

interesting science, served to confirm Mr. Cook in his first favourable opinion, and increase his confidence in the ultimate successful application of this power.

On Mr. Davenport's offer of an interest in the invention, Mr. Cook suspended an active business at home, and embarked in the enterprise with all his energies.

Through the last fall, and part of the winter, Messrs. Davenport and Cook spent their time in active experiments on this subject, and employed several hands in building models for their own use, as well as various sets to be sent to the different countries of Europe. They came to this city with their models in February last.

On ascertaining the expense of procuring patents in Europe, and the probable cost of building a large power, in order to give the most convincing proof of the value of this discovery, the proprietors found the amount too heavy to be met by themselves. The panic, as it is termed, had also commenced, and the miracle was not to be expected of meeting with an individual who had more money than he wanted for his own immediate use.

Under these circumstances, the proprietors, with the advice of their friends, threw the invention into a Joint Stock Association, consisting of three thousand Shares. By the Articles of Association, dated March 3, 1837, they deliver to Edwin Williams, Secretary of the American Institute, a portion of the stock, with which he is to raise funds, to "build models and machinery for giving to this invention its greatest possible value, for the benefit of the Stock Holders, (the constructions so made, to belong to the Association;) also, for securing the exclusive use of said invention in Europe, for the benefit of the Association."

Sufficient Stock has already been sold to prosecute improvements thus far, and to secure the patent in England, Ireland, Scotland, and the British dependances; which letters passed the King's seal a short time previous to his death. Preliminary arrangements have also been made for securing the patent in the remaining countries of Europe.

It is desirable immediately to sell sufficient stock to refund the expenses incurred in securing the patent for the remainder of Europe, and to enable the proprietors to build a large working power; which, as soon as put in operation, will no doubt advance the stock several hundred per cent.

Since the proprietors have been in this city they have been engaged in a series of rapid improvements in the power of this engine. So great have been the advances since the invention, that by the accurate experiment of lifting weights with the machine, it is found that the power has been increased five hundred and twenty-eight fold: that is, a single pound of iron wrought into a machine on the present arrangement, gives as much power as could have been obtained from a machine weighing five hundred and twenty-eight pounds, if made according to the first invention.

Notwithstanding this astonishing increase of power, and the prospect that it may yet be increased as much more, no departure from the principle of the original invention has been or can be made. That principle was the production of rotary motion by repeated changes of magnetic poles; this it is which is secured by patent; and no peculiarity of arrangement, or modification of the magnets, can be made to move without adopting the essence of the first invention. Hence no patent was probably ever obtained, which in its nature was more inviolable than this.

It has been often remarked that this machine carries with it the test of truth: that is, that the better its principles are understood; the more they are investigated, the more highly it is prized. It has been steadily growing into favour under the scrutiny of the best judges in the country, and has never failed to make a friend of every individual who well understands it. Error and imposition, on the contrary, always wither beneath investigation.

It is not to be expected that those whose interests and fortunes are embarked in the use of steam power, should feel very anxious for the success of this machine. Yet even in

this class there are several whose benevolence desires the good of all, and who are among its warmest supporters.

Among other illustrations, the proprietors have built five different grades of machines, varying in size and weight. From a principle in the course of the magnetic currents, and the improved energy of the magnets by induction, it is found that the power of the machines increase in a greater ratio than they are increased in weight.

As this power is procured by the action of the galvanic-fluid upon iron; as both iron and the galvanic fluid can be obtained in the greatest abundance; no reason *can* be assigned why any amount of power necessary for human purposes may not be brought into subserviency on this principle.

PROFESSOR SILLIMAN'S REMARKS.

FROM SILLIMAN'S AMERICAN JOURNAL OF SCIENCE AND ARTS,
NO. I. VOL. XXXII. APRIL, 1837.

Notice of the Electro-Magnetic Machine of Mr. Thomas Davenport of Brandon, near Rutland, Vermont.

MANY years have passed since motion was first produced by galvanic power. The dry columns of De Luc and Zamboni caused the vibration of delicate pendulums and the ringing of small bells, for long periods of time, even several years, without intermission.

In 1819—20, Professor Oersted, of Copenhagen, discovered that magnetism was evolved between the poles of a galvanic battery. Professor Sweigger of Halle, Germany, by his galvanic multiplier, succeeded in rendering the power manifest, when the galvanic battery was nothing more than two small wires, one of copper and the other of zinc, immersed in as much acidulated water as was contained in a wine-glass. The power thus evolved, was made to pass through many convolutions of insulated wire, and was thus augmented so as to deflect the magnetic needle sometimes even 90°. Professor Moll of Utretcht, by winding insulated wire around soft iron, imparted to it prodigious magnetic power, so that a horseshoe bar, thus provided and connected with a galvanic battery would lift over one hundred pounds. About the same time, Mr. Joseph Henry of Albany, now Professor Henry of Princeton College, by a new method of winding the wire, obtained an almost incredible magnetic force, lifting six or seven hundred pounds, with a pint or two of liquid, and a battery of corresponding size; nor did he desist, until a short time after, he lifted thousands of pounds, by a battery

of larger size, but still very small, (1830.) This gentleman was not slow to apply his skill to the generation of motion, and a successful attempt of his, is recorded in this journal, vol. xx. p. 340. A power was thus applied to the movement of a machine, by a beam suspended in the centre, which performed regular vibrations in the manner of a beam of a steam engine. This is the original application from which have sprung, or at least to which have succeeded, several similar attempts, both in this country and in Europe. A galvanic machine was reported to the British Association, in 1835, by Mr. McGauly, of Ireland, and he has renewed his statements of successful experiments, at the late meeting at Bristol. Mr. Sturgeon of Woolwich, England, also reports a galvanic machine as being in use on his premises for pumping water, and for other mechanical purposes.*

But, I believe that Mr. Davenport, named at the head of this notice, has been more successful than any other person in the discovery† of a galvanic machine of great simplicity and efficiency. During the last two or three years, much has been said of this discovery in the newspapers, and it is probable that in a future number of this Journal, drawings and an accurate description of the machine may be given. Having been recently invited to examine a working model, in two varieties of form, and to report the result, I shall now attempt nothing more than a general description, such as may render intelligible the account I am to give.

1. *The Rotary Machine, composed of Revolving Electro-Magnets, with Fixed Permanent Magnets.*

This machine was brought to New-Haven, March 16, 1837, by Mr. Israel Slade of Troy, N. Y., and by him set in motion for my examination. The moving part is composed of two iron bars placed horizontally, and crossing each other at right angles. They are both five and a half inches long, and

* Sturgeon's Annals of Electricity, Magnetism, &c., No. I. Vol. I., Oct. 1836. Mr. Sturgeon remarks, that, as he thought it might be improved, the machine has long since been laid by.— *Compiler.*

† Mr. Davenport appears to have been strictly the inventor of a method of applying galvanism to produce rotary motion.

they are terminated at each end by a segment of a circle made of soft iron ; these segments are each three inches long in the chord line, and their position, as they are suspended upon the ends of the iron bars, is horizontal.

This iron cross is sustained by a vertical axis, standing with its pivot in a socket, and admitting of easy rotation. The iron cross bars are wound with copper wire, covered by cotton, and are made to form, at pleasure, a proper connexion w th a circular battery, made of concentric cylinders of copper and zinc, which can be immersed in a quart of acidulated water. Two semicircles of strongly magnetized steel, form an entire circle, interrupted only at the two opposite poles, and within this circle, which lies horizontally, the galvanized iron cross moves in such a manner that its iron segments revolve parallel and very near to the magnetic circle, and in the same plane. Its axis at its upper end, is fitted by a horizontal cog-wheel to another and larger vertical wheel, to whose horizontal axis weight is attached and raised by the winding of a rope. As soon as the small battery, destined to generate the power, is properly connected with the machine, and duly excited by diluted acid, the motion begins, by the horizontal movement of the iron cross, with its circular segments or flanges. By the galvanic connexion, these crosses and their connected segments are magnetized, acquiring north and south polarity at their opposite ends, and being thus subjected to the attracting and repelling force of the circular fixed magnets, a rapid horizontal movement is produced, at the rate of two hundred to three hundred revolutions in a minute, when the small battery was used, and over six hundred with a calorimotor of large size. The rope was wound up with a weight of fourteen pounds attached, and twenty-eight pounds were lifted from the floor. The movement is instantly stopped by breaking the connexion with the battery, and then reversed by simply interchanging the connexion of the wires of the battery with those of the machine, when it becomes equally rapid in the opposite direction.

The machine, as a philosophical instrument, operates with

beautiful and surprising effect, and no reason can be discovered why the motion may not be indefinitely continued. It is easy to cause a very gradual flow of the impaired or exhausted acid liquor from, and of fresh acidulated water into, the receptacle of the battery; and whenever the metal of the latter is too much corroded to be any longer efficient, another battery may be instantly substituted, and that even before the connexion of the old battery is broken. As to the energy of the power, it becomes at once a most interesting inquiry, whether it admits of indefinite increase? To this inquiry it may be replied, that provided the magnetism of both the revolving cross and of the fixed circle can be indefinitely increased, then no reason appears why the energy of the power cannot also be indefinitely increased. Now, as magnets of the common kind, usually called permanent magnets, find their limits within, at most, the power of lifting a few hundred pounds, it is obvious that the revolving galvanic magnet must, in its efficiency, be limited, by its relation to the fixed magnet. But it is an important fact, discovered by experience, that the latter is soon impaired in its power by the influence of the revolving galvanic magnet, which is easily made to surpass it in energy, and thus, as it were, to overpower it. It is obvious, therefore, that the fixed magnet, as well as the revolving, ought to be magnetized by galvanism, and then there is every reason to believe that the relative equality of the two, and of course their relative energy, may be permanently supported, and even carried to an extent much greater than has been hitherto attained.

2. *Rotating Machine, composed entirely of Electro-Magnets, both in Fixed and Revolving Members.*

A machine of this construction has been this day, March 29, 1837, exhibited to me by Mr. Thomas Davenport, himself, who came from New-York to New-Haven for that purpose.

It is the same machine that has already been described, except that the exterior fixed circle is now composed entirely of electro-magnets.

The entire apparatus is therefore constructed of soft un-

magnetic iron, which being properly wound with insulated copper wire, is magnetized in an instant, by the power of a very small battery.

The machine is indeed the identical one used before, except that the exterior circle of permanent magnets is removed, and in its place is arranged a circle of soft iron, divided into two portions to form the poles.

These semicircles are made of hoop-iron, one inch in width, and one eighth of an inch in thickness. They are wound with copper wire, insulated by cotton—covering about ten inches in length on each semicircle and returning upon itself by a double winding, so as to form two layers of wire, making on both semicircles about one thousand and five hundred inches.

The iron was not wound over the entire length of one of the steel semicircles; but both ends were left projecting, and being turned inward, were made to conform to the bend of the other part; each end that is turned inward and not wound is about one third of the length of the semicircle. These semicircles being thus fitted up, so as to become at pleasure, galvanic magnets, were placed in the same machine that has been already described, and occupied the same place that the permanent steel magnets did before. The conducting wires were so arranged, that the same current that charged the magnets of the motive wheel, charged the stationary ones, placed around it, only one battery being used. It should be observed, that the stationary galvanic magnets, thus substituted for the permanent steel ones, were only about half the weight of the steel magnets. This modification of the galvanic magnet is not, of course, the best form for efficiency; this was used merely to try the principle, and this construction may be superseded by a different and more efficient one. But with this arrangement, and notwithstanding the imperfection of the mechanism of the machine,—when the battery, requiring about one quart of diluted acid to immerse it, was attached,—it lifted 16lbs. very rapidly, and when the weight was removed, it performed more than 600 revolutions per minute.

So sensible was the machine to the magnetic power, that the immersion of the battery one inch into the acidulated water, was sufficient to give it rapid motion, which attained its maximum when the battery was entirely immersed. It appeared to me that the machine had more energy with the electro-magnets than with those that were permanent; for, with the smallest battery, whose diameter was three inches and a half, its height five inches and a half, and the number of concentric cylinders, three of copper and three of zinc, the instrument manifested as great power as it had done with the largest batteries, and even with a large calorimotor, when it was used with a permanent instead of a galvanic magnet. With the small battery, and with none but electro or galvanic magnets, it revolved with so much energy as to produce a brisk breeze, and powerfully to shake a large table on which the apparatus stood.

Although the magnetization of both the stationary and revolving magnets was imparted by one and the same battery, the magnetic power was not immediately destroyed, by breaking the connexion between the battery and the stationary magnet; for, when this was done, the machine still performed its revolutions with great, although diminished, energy; in practice, this might be important, as it would give time to make changes in the apparatus, without stopping the movement of the machine.

It has been stated by Dr. Ritchie, in a late number* of the London and Edinburgh Phil. Magazine, that electro-magnets do not attract at so great a distance as permanent ones, and therefore are not well adapted for producing motion. On this point, Mr. Davenport made the following experiment, of which I was not a witness, but to which I give full credit, as it was reported to me by Mr. Slade, in a letter, dated New-York, March 24, 1837.

Mr. Davenport suspended a piece of soft iron with a long piece of twine, and brought one pole of a highly charged steel magnet within the attracting distance, that is, the distance at which the iron was attracted to the magnet; by measure-

* January, 1837.

ment, it was found that the steel magnet attracted the iron one inch and one-fourth. A galvanic magnet was next used of the same lifting power, and consequently of much less weight; the attracting distance of this magnet was found to be one inch and three-fourths, showing a material gain in favour of the galvanic magnet. Mr. Slade inquires, "has Mr. Ritchie's magnet been so constructed as to give a favourable trial to this principle?"† Mr. Davenport informs me that each increase in the number of wires has been attended with an increase of power.

CONCLUSIONS.

1. It appears then, from the facts stated above, that electro-magnetism is quite adequate to the generation of rotary motion.

2. That it is not necessary to employ permanent magnets in any part of the construction, and that electro-magnets are far preferable, not only for the moving, but for the stationary parts of the machine.

3. That the power generated by electro-magnetism may be indefinitely prolonged, since, for exhausted acids, and corroded metals, fresh acids and batteries, kept always in readiness, may be substituted, even without stopping the movement.

4. That the power may be increased beyond any limit hitherto attained, and probably beyond any which can be with certainty assigned, — since, by increasing all the members of the apparatus, due reference being had to the relative proportionate weight, size, and form of the fixed and movable parts — to the length of the insulated wires and the manner of winding them — and to the proper size and construction of the battery, as well as to the nature and strength of the acid or other exciting agent, and the manner of connecting the battery with the machine it would appear certain, that the power must be increased in some ratio which experience must ascertain.

† This question I am not able to answer, as I have not seen any account of the apparatus or of the experiment, but only of the result.

5. As electro-magnetism has been experimentally proved to be sufficient to raise and sustain several thousands of pounds, no reason can be discovered why,—when the acting surfaces are, by skilful mechanism, brought as near as possible, without contact,—the continued exertion of the power should not generate a continued rotary movement, of a degree of energy inferior indeed to that exerted in actual contact, but still nearly approximating to it.

6. As the power can be generated cheaply and certainly — as it can be continued indefinitely — as it has been very greatly increased by very simple means — as we have no knowledge of its limit, and may therefore presume on an indefinite augmentation of its energy, it is much to be desired, that the investigation should be prosecuted with zeal, *aided by correct scientific knowledge*, by *mechanical skill*, and by *ample funds*. It may therefore be reasonably hoped, that science and art, the handmaids of discovery, will both receive from this interesting research, a liberal reward.

Science has thus, most unexpectedly, placed in our hands a new power of great but unknown energy.

It does not evoke the winds from their caverns; nor give wings to water by the urgency of heat; nor drive to exhaustion the muscular power of animals; nor operate by complicated mechanism; nor accumulate hydraulic force by damming the vexed torrents; nor summon any other form of gravitating force; but, by the simplest means, — the mere contact of metallic surfaces of small extent, with feeble chemical agents, a power every where diffused through nature, but generally concealed from our senses, — is mysteriously evolved, and by circulation in insulated wires, it is still more mysteriously augmented, a thousand and a thousand fold, until it breaks forth with incredible energy; there is no appreciable interval between its first evolution and its full maturity, and the infant starts up a giant.

Nothing since the discovery of gravitation and of the structure of the celestial systems, is so wonderful as the power

evolved by galvanism; whether we contemplate it in the muscular convulsions of animals, the chemical decompositions, the solar brightness of the galvanic light, the dissipating consuming heat, and more than all, in the magnetic energy, which leaves far behind all previous artificial accumulations of this power, and reveals, as there is full reason to believe, the grand secret of terrestrial magnetism itself.

NEW-HAVEN, *March* 31, 1837. B. S.

CLAIM OF THOMAS DAVENPORT.

In the words of the patent taken out, this invention "consists in applying magnetic and electro-magnetic power as a moving principle for machinery, in the manner described, or in any other substantially the same in principle."

"Mr. Davenport first saw a galvanic magnet in December, 1833, and from the wonderful effects produced by suspending a weight of 150 lbs. from a small galvanic magnet, he immediately inferred, without any knowledge of the theory or the experiments of others, that he could propel machinery by galvanic magnetism. He purchased the magnet and produced his first rotary motion in July, 1834. In July, 1835, he submitted his machine to Professor Henry of Princeton, New-Jersey, also without any knowledge of Professor Henry's experiments in producing a vibratory motion. From this gentleman he received a certificate, testifying to the importance and originality of the invention."

Mr. Davenport is, by occupation, a blacksmith, with only a common education, but with uncommon intelligence; his age about thirty-five. Mr. Ransom Cook of Saratoga Springs, is associated with Mr. Davenport, and has rendered essential service by the improvements he has made in the machine, and by his assistance in bringing the subject before the public in the most effectual way. Arrangements have been made to take out the patent in Europe.

P. S. The proprietors are constructing a machine of seven inches in diameter, and also one of two feet in diameter. Galvanic magnets will be used as the moving and stationary magnets of each.

EXTRACTS FROM THE NEWSPAPERS.

[From the Saratoga Sentinel, January 3, 1837.]

HIGHLY IMPORTANT INVENTION.

ELECTRO-MAGNETIC ENGINE.

In company with Dr. Steel and several other gentlemen, we called upon Messrs. Davenport and Cook of this village, on Saturday, with a view of examining the Electro-Magnetic Engine, invented by the senior partner.

The ingenuity, yet simplicity of its construction, the rapidity of its motion, together with the grandeur of the thought that we are witnessing the operations of machinery propelled by that subtle and all-pervading principle electricity, combine to render it the most interesting exhibition we have ever witnessed.

Although we shall say something on the subject, it is perhaps impossible to describe this machine by words alone, so as to give more than a faint idea of it to the reader.

It consists of a stationary magnetic circle, formed of disconnected segments. These segments are permanently charged magnets, the repelling poles of which are placed contiguous to each other. Within the circle stands the motive wheel, having the projecting galvanic magnets, which revolve as near the circle as they can be brought without actual contact. The galvanic magnets are charged by a battery, and when so charged, magnetic attraction and repulsion are brought into requisition in giving motion to the wheel—the poles of the galvanic magnets being changed more than a thousand times per minute.

Having in its construction but one wheel, revolving with no friction except from its own shaft, and from the wires connecting it with the galvanic battery, the latter of which can scarcely be said to impede the motion in any degree, the durability of this engine must be almost without limit.

There is no danger to be apprehended from fire or explo-

sions; and we understand it is the opinion of scientific gentlemen who have examined it, that the expense of running this machine will not amount to one fourth as much as that of a steam engine of the same power.

From the time when the Greek philosopher supposed the magnet possessed a soul, its mysterious power has been regarded with increasing interest and attention to the present day. In addition to its utility in the compass, thousands have laboured in vain attempts to obtain through its agency a rotary motion. So intense has been the application of some to this subject, that in the attempt they have even lost that elevating attribute of our species, reason. It was reserved for Mr. Davenport to succeed where so many had failed.

He commenced his labours more than three years ago, and prosecuted them under the most discouraging and unfavourable circumstances—sustained by a constitutional perseverance and a clear conviction of ultimate success. He obtained the first rotary motion in July, 1834; since which time he has devoted his whole attention to improvements in his machine. During this period it has passed through five different modifications, and is now brought to such a state of simplicity and perfection (having apparently the fewest possible number of parts,) that the proprietors consider no further important alteration desirable, except in the due proportions of the different magnets, in which they are daily improving.

We were shown a model in which the motive wheel was five and a half inches diameter, which elevated a weight of *twelve pounds*. And to illustrate the facilities for increasing the power of this engine, another model was exhibited to us with a motive wheel of eleven inches in diameter, which elevated a weight of *eighty-eight pounds*. Although these models have been for some time in progress, and we have occasionally been permitted to examine them, we have waited till the present period, when the practicability of obtaining a rapid and unlimited increase of power seems to be placed beyond a doubt, before expressing an opinion, or calling the public attention to the subject.

If this engine answers the expectations of the inventor, (and we believe no one can assign a *reason* why it should not,) it is destined to produce the greatest revolution in the commercial and mechanical interests which the world has ever witnessed. We may consider the period as commencing when machinery in general will be propelled by power concentrated upon the plan of this engine; when the vessels of all commercial nations will be guided to their point of destination and urged forward in their course by the same agent, triumphantly contending against winds and tides, with the silent sublimity of unseen but irresistible power.

The prophetic ken of science is happily exhibited by Dr. Lardner, in his treatise on the Steam Engine. His far-seeing genius seems to have anticipated the invention of which we are speaking. "Philosophy," said he, "already directs her finger at sources of inexhaustible power in the phenomena of electricity and magnetism, and many causes combine to justify the expectation that we are on the eve of mechanical discoveries still greater than any which have yet appeared; and that the steam engine itself, with the gigantic powers conferred upon it by the immortal Watt, will dwindle into insignificance in comparison with the hidden powers of nature still to be revealed, and that the day will come when that machine, which is now extending the blessings of civilization to the most remote skirts of the globe, will cease to have existence except in the page of history."

From the integrity, perseverance, and mechanical skill of Ransom Cook, Esq. who has himself made an important invention in this engine, and has undertaken to bring the same into use, we anticipate a speedy introduction of its merits to the public. It is hoped that he may prove a second Livingston to another Fulton. He is about to depart for our large cities, in some of which he contemplates the erection of powers for mechanical purposes.

Several individuals, agents of Messrs. Davenport & Cook, are also departing with models to secure letters patent in the different countries in Europe and South America.

[From the New-York Herald, April 27, 1837.]

A REVOLUTION IN PHILOSOPHY;

DAWN OF A NEW CIVILIZATION.

We mentioned slightly, the other day, a few particulars, descriptive of the electro-magnetic machine now preparing for exhibition in this city. We shall now go a little deeper into this most extraordinary discovery — probably the greatest of ancient and modern times — the greatest the world has ever seen — the greatest the world will ever see.

Some months ago a notice of the discovery was published in a Saratoga paper. It did not create much attention. Many of the ignorant and impudent pretenders of the day, who assume to control public opinion, laughed and ridiculed the idea of an electro-magnetic machine. We saw the notice at the time in the Saratoga paper — read it — perceived at once its principle and probability — and republished it. We have since seen and examined the machine, or rather several machines, and must be permitted to say, that it far exceeds our most sanguine expectations, in originality, power, simplicity, and magnitude.

In February last, Mr. Davenport took out a patent. He has since exhibited his machine to Professor Silliman of New-Haven, who has pronounced an opinion entirely in its favour.

It is difficult to describe its operations so as to be understood by the general reader. The machine now in this city, consists of two parts — the galvanic apparatus and the magnetic. The galvanic apparatus consists of the usual galvanic trough or jar, with the convolutions of copper and zinc plates, immersed in acidulated water, and united at the top with galvanic conductors. The voltaic pile or battery was formerly used in galvanic experiments — but the trough is now generally the mode of generating the mysterious fluid.

The next branch of the apparatus is the magnetic wheel. This is formed of several magnets of a semicircular form, surrounding a wheel of a singular form, that has to be seen

to be understood. The simple application of the conductors of the galvanic trough to the conductors of the magnetic horizontal wheel, at once sets the apparatus in motion. This motion is produced by the invisible power of electricity or galvanism acting on the magnets by a certain arrangement of the parts. A child can set it agoing or stop its motion. It only requires a simple contact of the conductors to bring the power into action — and to stop the whole, the removal of these conductors is sufficient.

The only waste of material is in the plates of zinc, which, by the action of the acidulated water, slowly corrodes. Its power is immense. A small galvanic trough of ten inches deep and six inches diameter, with the alternate convolutions of zinc and copper, immersed in the acid, will generate galvanic power enough to set the magnetic wheel of six inches in motion, equal to raise a weight of twenty-eight pounds. A larger trough, which I tried by a heavy weight, generated 400 pounds resistance or energy. The calculation is, that a galvanic, or, as it is called, an electro-magnetic engine, constructed on this principle, will cost only one-tenth the expense of steam power, and only occupy one half of the space. There can be no doubt, in our mind, but the days of steam power, and animal power, and water power, are gone for ever. This is no idle vision — no fancy's sketch.

Messrs. Davenport and Cook are now busy constructing a larger machine than the present one they have, for the purpose of demonstrating to the community the great importance and truth of their truly magnificent discovery.

We are in the commencement of a revolution in philosophy, science, art, and civilization. The occult and mysterious principle of galvanism is now beginning to be developed in all its magnificence and energy. All the phenomena of nature, our Vermont Newton believes, can be explained by this mysterious principle. Gravitation, life, muscular action, the thunder of heaven, the aurora borealis — every thing in motion we see around us, receives its energy from this secret and mysterious principle. "Your brain," said Mr. Davenport

to me, "is only a galvanic trough, formed of convolutions, or layers for generating the fluid — and when you walk or move, you do it by the galvanic action of that trough, operating on the limbs by its conductors, the nerves and muscles." The lovely women walking Broadway are, therefore, so many beauteous galvanic engines in motion.

Thus much for to-day. It is utterly impossible to give vent to all those burning thoughts which crowd upon our mind at the contemplation of this discovery. It surpasses any discovery of ancient or modern times. The generalization of this principle, and its undoubted identification with all the phenomena of nature — with motion — with animal life — with earthquakes — with gravity — with electricity — with the motion of the earth and planets round the sun, must and will create an entire revolution in all science, in all art, in all philosophy, and in all future civilization. Indeed we may go further, and however droll it may appear, we have strong suspicions that the friendship, esteem, and the mysterious love between the sexes is founded on the same principle with which Mr. Davenport turns his wheel, and the lightning flashes from heaven — and the aurora borealis spreads out its garments of rosy light in the sky — and the very planets themselves run their races round the sun from eternity to eternity.

Enough for the present. We have long been a student in chemistry, electricity, galvanism, and such like sciences. We shall illustrate our views at our leisure. Meantime we bid all prepare for an organic revolution in science, philosophy, religion and civilization. We are just entering upon a wonderful age.

[From the Baltimore Daily Gazette, May 3, 1837.]

Our readers have seen by the article which we copied on Monday from the American Journal of Science, and which was written by the justly celebrated Professor Silliman, the conductor of that valuable Journal, that he has come to the

conclusion from the facts within his knowledge, "that electro-magnetism is quite adequate to the generation of rotary motion; that the power so generated may be indefinitely prolonged — that it may be increased beyond any limit hitherto attained; probably beyond any which can be with certainty assigned — and that it can be generated cheaply and certainly." This deliberate opinion, formed by a prudent, scientific man, after repeated experiments, and so confidently expressed as we find it in the essay published, ought to be proof sufficient to satisfy every reasonable mind, that, in the language of the Professor, "Science has placed in our hands a new power of great but unknown energy — a power everywhere diffused through nature." The practical use of this power will effect changes of the most extraordinary description both by land and sea — water, wind, and steam, long the useful and obedient servants of man, if not rendered wholly unnecessary as motive agents, will become comparatively unimportant, and the labour of the world in the movements of all kinds of machinery — in its agriculture, its transportation, and travelling — will soon be principally performed by the agency of electro-magnetism, and the general benefit to man will be immense from the safety and cheapness with which this new agent can be employed.

It must be obvious that the use of such a power — so safe, so cheap, so free from every thing that could cause annoyance in its use — will be, to Rail Roads, an acquisition of immense value — in the reduction of the expenses of transportation. The costly article of fuel with all the annoyances of sparks, cinders, tender and watertank, and of a special attendant to the fire in each engine — will be wholly dispensed with. This saving for one engine in daily use throughout the year, may be reasonably estimated at three thousand dollars. — And in repairs there will be a saving more than equal to the whole probable expense of transportation, and repairs of a locomotive, moved by the newly discovered application of power.

[From the N. Y. Courier and Enquirer, July 31, 1837.]

ELECTRO-MAGNETIC MACHINE.

The boldness, ingenuity, and perseverance of the inventors of this machine have been crowned with a success in their experiments thus far, which leaves little room for theory, or for doubt of eventual triumph. The application of electro-magnetism to numerous and important mechanical purposes, is no longer matter of question, even if no greater power were attainable than that which we lately saw in actual operation. This invention of Messrs. DAVENPORT and COOK, if brought into use upon a large scale, which we have now full right to anticipate, is destined to produce consequences that almost baffle calculation. The immediate result would be the speedy substitution of electro-magnetic engines for nearly all other motive and mechanical powers now in use. Results would follow as mighty as those which steam has wrought in the industry and intercourse of mankind within the last fifty years. It appears to be now established by the very satisfactory experiments of these gentlemen, that the power is capable of indefinite increase, and there seems no more difficulty in calculating the increase of power from increased proportions in the different members of the apparatus, than there is in the same calculation of the force of a steam engine of given dimensions and proportions. It is most confidently anticipated (and we think from satisfatory data,) that this new power will possess very decided advantages over steam, in point both of compactness and weight of apparatus. That as great a power may be obtained, for instance, from such an engine weighing two tons, as is usually obtained from a steam engine occupying double the space and weighing three tons.

But in point of economy, — the grand desideratum in all engines, — the electro-motive power will possess the advantage still more decided, if the calculations of which we have heard are found to be correct — of the expense of working such machines of larger size.

In *construction*, the saving will be immense. In safety and durability, there can be no comparison. All the disagreeable and dangerous incidents, too, by steam, are at once removed. There is no noise — no smoke — no whizzing of steam — no bursting of boilers. The most irresistible of all the mysterious and wonderful agents of nature operates its miracles in perfect silence and repose. The same terrible element that is seen in the most vivid and appalling flash of the lightning — the same that awes us in the rolling thunder — that in the dreaded thunderbolt topples down the proudest turrets, and the strongest spires from their giddy heights — or uproots from their foundations the firmest walls — the hugest oaks, and the most impregnable fortresses, is here seen chained and subdued, like the galley-slave at his oar, labouring peacefully and unresistingly in any occupation that human ingenuity and caprice may assign to it. We do not speak of what may be, but what is already accomplished. Yes, in the country of Franklin, who first drew the lightning down from the clouds, and played with it in his hands — at the distance of little more than half a century, have two natives of the same soil been the first to convert the same great element to a useful and humble servant of mankind. In the view of this sublime result, if we may justly say of Franklin, "*Fulmen eripuit cœlo*," we may almost say with equal justice of these inventors, that they have learned how we may

——— "Wield these elements,
"And arm us with the force of all their regions."

Even, as we have before observed, if no greater power were attainable than what they are now daily exhibiting — what we had ourselves the other day the pleasure of seeing in full and triumphant operation — they have invented a machine which is capable of being applied more economically to a vast variety of manufacturing purposes than any other known power. For goldsmiths' and silversmiths' lathes, for silk and other reels, for cotton spindles, for an infinite variety of polishing purposes, for glass cutters, for ivory turners, &c.,

it is an invaluable power. In illustration of this, we may mention the fact that a goldsmith of this city who witnessed the operation of the smaller machine, offered the proprietors $25 for it, for his own manufacturing purposes. Such machines, it is supposed, might be constructed for 5 or 6 dollars. The larger machine makes from 1000 to 1200 revolutions per minute.

At the same time, in announcing these brilliant results already attained by our ingenious and meritorious fellow-citizens, we desire to impress upon the attention of intelligent capitalists, that to put this motive power into operation upon a scale commensurate with the public wishes and expectation, it is necessary that the remaining shares of the 200 which are offered for sale, should be taken up, and the principle will then be at once put into operation upon a scale which will satisfy the most incredulous. Surely, when they reflect upon the vast importance of the results to be obtained, and now within reach, they will not hesitate to come forward and take some few shares in an undertaking which promises so rich a harvest of profit, as well as so incalculable a benefit to our country and mankind in general. The whole interest in the invention now secured by patent in this country and Great Britain, and arranged to be secured in the rest of Europe, is to be the property of the share-holders who now engage in the undertaking. The two hundred shares out of 3000 in which it is divided, now offered to the public, are only intended to furnish capital enough to make an ample experiment, and no more will be offered until that shall have been thoroughly done. *E. Williams, Esq.*, the agent and trustee of the proprietors, has made already great progress in perfecting these arrangements; but an adequate capital for the contemplated experiment on a large scale will require the sale of the whole 200 shares. When that has been accomplished, if the result is satisfactory, the value of the stock will of course be enhanced in a proportion which we need not now calculate. But at all events, enough has already been established of the utility, as we said before, of this invention for different

manufacturing purposes to make the stock valuable if no greater power should be gained.

If the rough estimate we have formed of the power of the machine we saw in operation be any where near correct, and the increase is only in strict proportion to the increase of proportions, we know of no power in use capable of exerting an equal force within the same dimensions. Our estimate is based upon what we saw it actually perform, and we rate it below what others who have witnessed, have supposed it to be in reality.

At all events, this successful application of the mysterious power of galvanism to mechanical purposes, forms a most remarkable era in the history of science and mechanical skill. We regret that the numerous demands upon our columns prevent us from giving various calculations and descriptions more in detail, which would tend to elucidate the vast importance of this subject to the community. Those, however, who feel disposed to take an interest in the enterprise, and to hasten its application to navigation on a scale that may test its practicability in the fullest manner, may easily avail themselves of a personal inspection and examination, upon applying to the agent of the proprietors, at his office 76 Cedar-street. The explanations given by Mr. Cook himself, will enable them to duly appreciate the ingenuity and power which are beautifully illustrated in the model we have viewed with so much pleasure.

[From the N. Y. Evening Star, August, 1837.]

DAVENPORT'S ELECTRO-MAGNETIC MACHINE.

In concurrence unanimously we believe with all who have witnessed the operations of this extraordinary and simple apparatus, and listened to the lucid and eloquent explanations of Mr. Cook; we confess our utter amazement at the prodigious changes which it manifestly foretells in the application of an entire new and immeasurable agent of mechanical power; and at the same time, while we see and admire, acknowledge ourselves for want of language to sustain us,

utterly incompetent to impart any correct conception of this marvellous invention to our readers. All we say is, "go and be convinced."

DESCRIPTION.

If we were to attempt to give our readers some faint notion of this machine, we would say that it consists of a wheel composed of two iron semicircular arcs, cut across, so as to interrupt their formation into a complete circle. That within these are two iron bars or shafts, crossing at right angles, bearing smaller segments of circles on their extremities, nearly touching, as they revolve, the above outer circle, which is fixed. The whole of these are horizontal and covered with silk, and then wound round closely and spirally with copper wire, the wire itself covered with cotton and varnished. On the upright shaft below are two small corresponding semicircular arcs, cut as above. Now these are all connected by two flat copper wires, which lead to Hare's Galvanic Battery of concentric copper and zinc plates, in a solution of sulphate of copper. These generate the electric stream, like fuel to a fire engine, and it is by the two upright wires that touch the circle below, as their ends alternately rub in the rotatory motion against the inside of the two semicircular arcs into which that fixed circle is divided, that the extremities of the semicircular pieces above are alternately made to change their positive and negative poles by the ascending current of galvanism, and thus the principle of repulsion and attraction made to act in concert on the four segments of the shafts above described — keeping up by the magnetization produced a swift rotatory motion, which in this machine raises 200lbs. one foot in a minute. So rapid is the change of poles and the electric velocity of the stream of galvanism, that it makes 32,000 revolutions around the wires in a minute. It is a sublime but not wild idea of Mr. Cook, that a ship's bottom covered with suitable plates and the ocean for its bath, may drive herself along with incredible velocity, at the same time generating abundance of hydrogen to light her onward upon the deep.

It is a highly-important consideration that electro-magnetic power may be multiplied in its application without being exhausted. Thus, if we can obtain enough force to move *one* spindle for spinning Cotton, *one thousand* or *five thousand* spindles may be turned by the same galvanic or electric current, without any increase of power. Each spindle being made magnetic, and all of them connected with wires, the whole of them may be operated upon by the wires, from only one galvanic battery. This fact is admitted by all scientific men, as far as we have heard. Thus it will be seen that all the spindles in any Cotton Manufactory in America or Europe may be set and continued in motion by one of Davenport's small machines. It is not necessary, however, to stop here, as no reason can be given why the power may not be indefinitely increased.

We take the liberty of making an estimate of the value of the invention, supposing the ingenious proprietors to go no further, feeling confident, at the same time, that we are under the mark, particularly as the rights of the patent are secured in Europe, which we do not include.

The power already obtained is applicable then to the following mechanical purposes, among others, which will readily occur to our readers: —

	Patent rights, valued at
Cotton Spinning,	$300,000
Silk reeling, &c.,	130,000
Rope walks, twine, &c.,	50,000
Watchmakers and Jewellers,	50,000
Glass Cutters,	25,000
Turners in wood and ivory,	10,000
Wire winders,	5,000
Panoramas,	5,000
Domestic purposes, such as churning, pumping, roasting jacks, washing machinery, &c.	25,000
Total,	$600,000

In reference to the means necessary to carry out and develope the powers of this important invention, we regret that our Government is so constituted that aid cannot, without specific appropriation, be obtained for the advancement of this plan. Individual means must be resorted to. What would have been the fate of steam navigation, locomotives, &c., had Fulton been destitute of a fostering and protecting arm? We would say to men of wealth, "Come forward — take a share. What is $100 to risk in an experiment which has already developed so much power?" Every mechanic who could use that power, and has $100, should take a share; it may be worth $1000 hereafter.

[From the N. Y. Evening Star, August, 1837.]

DAVENPORT'S DISCOVERY.

As we have given our views cursorily on this great invention, we annex those from a source which, if known, would be deemed higher authority than any thing we ourselves can utter.

We see the machine in motion; we witness and feel its exercise of power; but simple as it is in construction, we cannot describe the operation of the invisible agent which moves it so as to be understood. It would be useless to follow Professor Silliman and others in the same path; words are inadequate; it must be seen, examined, and explained before it can be appreciated.

The most scientific gentlemen of the present day incline to the opinion, that light, heat, galvanism, magnetism, and electricity, are all modifications of the same principle. That this exerts a controlling influence throughout the vast expanse of nature. That its presence is alike manifested in the internal warmth of our planet; its beautiful mineral formations; the variegated foliage that covers it; in all muscular action; the active energy of man; the expressive eye of woman; the vivid glare of lightning; the startling crash of thun-

der; and the silent sublimity with which the unnumbered worlds move in their rapid and harmonious course.

When this grand and universal principle is brought into subserviency by man, as demonstrated in the Electro-Magnetic Engine, can there be a rational doubt as to the final success of this invention? Without danger from fire, explosion, or electric shocks—there is no objection to its becoming an appendage to every farming and household establishment. It may saw the wood, churn the butter, thresh the grain, and gin the cotton of the agriculturist. Spinning, weaving, and other manufactories may be conducted by the poor of our cities in their respective dwellings, without congregating the wretched and vicious at some remote water fall.

But it is in a commercial view that it exhibits, in prospective at least, an importance combined with the finest sublimity. It is well known that sea water forms an active bath for the galvanic battery when kept up by frequent changes. Is there any insurmountable objection to arranging the sheathing of the vessel so as to form a battery, and, with the ocean for its bath and the application of magnetic power, "drive the ship onward in her course and guide her to the point of destination by the same agent?"

When the use of steam is proposed in conducting our distant commerce, we cannot avoid the reflection that on the vast deep the perils of wind and waves are sufficient without adding those of fire and explosion.

We know there are many who "will not admit that any thing can be which has not before been;" who engage in no enterprise of their own, and predict the failure of all others —preserving a good opinion of their own penetration by the fulfilment of one in a hundred of their predictions—who seem to think that "wisdom will die with them," and are always prating of the visionary, the rash, and enthusiastic.

We say in reply, that no valuable or grand achievement was ever accomplished, except by the very men who are thus stigmatized. Such were the patriots and soldiers of the

revolution; such are the inventors of all our improvements; such, in short, are the benefactors of the world.

While Mr. Davenport was exhausting his health and resources in producing the invention, and when joined by Mr. Cook, both were expending all their available funds in experiments, the value of which were not appreciated by others; they were quietly allowed to continue their exertions, enjoying the pity and ridicule of some, but the envy of none.

Now, however, when such invaluable results are anticipated from a full developement of the power and utility of the invention, they will no doubt be often invited to divide with others, both emoluments and fame, before they had themselves secured in either. But a just and indignant public will frown these pseudo inventors back to their original obscurity.

We hope this invention may not languish for the want of the necessary funds to bring it into successful operation. The stock on sale is devoted expressly to that purpose, and purchasers can enjoy the gratifying reflection of contributing to a most praiseworthy enterprise, with the prospect of a rich reward. Was it a lottery, where the chances were a thousand to one against the purchaser, it would be rapidly sold. We believe the chances may be reversed in favour of an investment in this case; for there is no one to our knowledge who is acquainted with the science and the machine, who does not speak with confidence of its entire success.

[From the N. Y. Commercial Advertiser, August, 1837.]

ELECTRO-MAGNETISM.

We have said very little hitherto, respecting the machines invented by Mr. Davenport, or by Messrs. Cook and Davenport, in which, the public have been given to understand, those gentlemen have succeeded in applying the tremendous energy of the galvanic battery to the creation of a rotary motion,

It has not been that we were blind or indifferent to the vast importance of this application, if successfully established, but because we could not overcome a lingering doubt as to the possibility of increasing the power to such an extent, as should be really serviceable in the propulsion of large machinery. That a rotary motion had been produced, with small apparatus, we knew long ago; but we knew also that many scientific men doubted whether the enlargement of the apparatus would give even a proportional increase of power; and being advised that Messrs. Cook and Davenport were still making experiments, with reference to this very question, we determined to wait for the result, and then form the best opinion we could, on our own judgement and very moderate stock of philosophical and mechanical knowledge.

Yesterday we attended at the office of Mr. Williams, in Cedar-street, and there had the pleasure of seeing the machines, and hearing the explanations given by Mr. Cook, in a brief, informal lecture to a party of some twenty gentlemen, among whom was Professor Hare of Philadelphia. In the face of so distinguished a chemist as that gentleman, we should not venture to pronounce a decided opinion; and we hope that his impressions of the discovery, or invention, will soon be made public; but there can be no undue assumption of confidence or judgement, in saying that enough has been accomplished by Messrs. Cook and Davenport, to justify them in expecting and asking from the public the means of constructing their apparatus on a scale of such magnitude, as shall bring the only remaining point of question to a final decision.

They have made a small machine, scarcely occupying more surface than one half of this sheet, in which an iron magnetized wheel, of about six inches diameter and weighing six pounds, is made to revolve with the terrific velocity of 1000 times in a minute, and with such power as to raise a weight of 200 pounds one foot, in less than the same space of time — the galvanic power being generated in three small

sets of concentric cylinders, scarcely larger than a quart measure.

Here then we have a power, inexhaustible, procured and maintained at trifling expense, occupying very little room, and *perfectly free from all risk of accident*, sufficient for the propulsion of such small machinery as is employed in a hundred different occupations, such as those of jewellers, turners, stocking-weavers, watch-makers, glass-cutters, &c. &c. So far the result is secure — to this extent the utility of the invention is manifest; and even at this point it is of no common importance.

But the inventors are confident, that with larger apparatus, and certain improvements which they entertain strong hopes of making, the same wonderful power may be employed in propelling the largest machinery, such as that of vessels, cotton factories, printing presses, and saw mills. All they want is a sum of money, small in comparison with the vast magnitude of the results expected to be obtained; and it imports much to the interest, as well as to the honour of our country, that this sum of money be placed at their disposal.

[From the N. Y. Evening Post.]

THE ELECTRO-MAGNETIC MACHINE.

We learn that some recent improvements have been made in the application of electricity as a moving power to machinery. A larger apparatus than the one hitherto exhibited has been constructed under the direction of Mr. Cook, now in this city, which is to set in motion a turning lathe, in order that those who take an interest in the invention may see it at work. Nothing but the difficulty of the times now stands in the way of demonstrating the application of this power on a large scale to machinery of the most ponderous description.

It is to be hoped that the means for doing this will soon be obtained — it is to be hoped for the interests both of science and humanity. The application of this new principle of motion, if successful, as we have but little doubt it will be, is one of the most wonderful inventions of the age, and will hand down the name of its discoverer to future times along with those of Franklin and Fulton. It will furnish a power procurable, with the greatest cheapness and facility, in quantities to suit machines of any size, manageable with the greatest ease and free from any danger except such as necessarily belongs to rapid motion produced by any cause.

Had this discovery been brought before the public ten years ago, or even a year ago, we should probably ere this have seen the electric fluid driving boats and turning spinning jennies. We understand that the proprietors of the invention offer very liberal terms to such as are disposed to contribute to the means of carrying it into effect.

FROM MRS. SOMERVILLE'S TREATISE

ON THE

CONNEXION OF THE PHYSICAL SCIENCES.

ELECTRICITY.

Electricity is one of those imponderable agents pervading the earth and all substances, without affecting their volume or temperature, or even giving any visible sign of its existence when in a latent state, but when elicited developing forces capable of producing the most sudden, violent, and destructive effects in some cases, while in others, their action, though less energetic, is of indefinite and uninterrupted continuance. These modifications of the electric force, incidentally depending upon the manner in which it is excited, present phenomena of great diversity, but yet so connected as to justify the conclusion that they originate in a common principle.

Electricity may be called into activity by mechanical power, by chemical action, by heat, and magnetic influence; but we are totally ignorant why it is roused from its neutral state by such means, or of the manner of its existence in bodies; whether it be a material agent, or merely a property of matter. However, as some hypothesis is necessary for explaining the phenomena observed, it is assumed to be a highly elastic fluid, capable of moving with various degrees of facility through the pores or even the substance of matter; and as experience shows that bodies in one electric state attract, and in another repel each other, the hypothesis of two kinds, called positive and negative electricity, is adopted, but whether there really be two different fluids, or that the mutual attraction and repulsion of bodies arises from the redundancy and defect of their electricities, is of no conse-

quence, since all the phenomena can be explained on either hypothesis. As each electricity has its peculiar properties, the science may be divided into branches, of which the following notice is intended to convey some idea.

Substances in which the positive and negative electricities are combined, being in a neutral state, neither attract nor repel; but there is a numerous class called electrics, in which the electric equilibrium is destroyed by friction; then the positive and negative electricities are called into action or separated; the positive is impelled in one direction, and the negative in another; those of the same kind repel, whereas those of different kinds attract each other. The attractive power is exactly equal to the repulsive force at equal distances, and when not opposed, they coalesce with great rapidity and violence, producing the electric flash, explosion, and shock; then equilibrium is restored, and the electricity remains latent till again called forth by a new exciting cause. One kind of electricity cannot be evolved without the evolution of an equal quantity of the opposite kind; thus, when a glass rod is rubbed with a piece of silk, as much positive electricity is elicited in the glass as there is negative in the silk. The kind of electricity depends more upon the mechanical condition than on the nature of the surface, for when two plates of glass, one polished and the other rough, are rubbed against each other, the polished surface acquires positive, and the rough negative electricity. The manner in which the friction is formed also alters the kind of electricity. Equal lengths of black and white ribbon, applied longitudinally to one another, and drawn between the finger and thumb, so as to rub their surfaces together, become electric; when separated, the black ribbon is found to have acquired negative electricity, and the white positive: but if the whole length of the black ribbon be drawn across the breadth of the white, the black will be positively, and the white negatively electric when separate. Electricity may be transferred from one body to another in the same manner as heat is com-

municated, and, like it too, the body loses by the transmission. Although no substance is altogether impervious to the electric fluid, nor is there any that does not oppose some resistance to its passage, yet it moves with much more facility through a certain class of substances called conductors, such as metals, water, the human body, &c., than through atmospheric air, glass, silk, &c. which are therefore called non-conductors; but the conducting power is affected both by temperature and moisture.

Bodies surrounded with non-conductors are said to be insulated, because, when charged, the electricity cannot escape; but when that is not the case, the electricity is conveyed to the earth, which is formed of conducting matter; consequently it is impossible to accumulate electricity in a conducting substance that is not insulated. There are a great many substances called non-electrics, in which electricity is not sensibly developed by friction, unless they be insulated, probably because it is carried off by their conducting power as soon as elicited. Metals, for example, which are said to be non-electrics, can be excited, but, being conductors, they cannot retain this state if in communication with the earth. It is probable that no bodies exist which are either perfect non-electrics or perfect non-conductors; but it is evident that electrics must be non-conductors to a certain degree, otherwise they could not retain their electric state.

It has been supposed that an insulated body remains at rest, because the tension of the electricity, or its pressure on the air which restrains it, is equal on all sides; but when a body in a similar state, and charged with the same kind of electricity, approaches it, that the mutual repulsion of the particles of the electric fluid diminishes the pressure of the fluid on the air on the adjacent sides of the two bodies, and increases it on their remote ends; consequently that equilibrium will be destroyed, and the bodies, yielding to the action of the preponderating force, will recede from or repel each other. When, on the contrary, they are charged with opposite electricities, it is alleged that the pressure upon the

air on the adjacent sides will be increased by the mutual attraction of the particles of the electric fluid, and that on the further sides diminished; consequently that the force will urge the bodies towards one another, the motion in both cases corresponding to the forces producing it. An attempt has thus been made to attribute electrical attractions and repulsions to the mechanical pressure of the atmosphere; it is, however, more than doubtful whether these phenomena can be referred to that cause, but certain it is that, whatever the nature of these forces may be, they are not impeded in their action by the intervention of any substance whatever, provided it be not itself in an electric state.

A body charged with electricity, although perfectly insulated, so that all escape of electricity is precluded, tends to produce an electric state of the opposite kind in all bodies in its vicinity; positive electricity tends to produce negative electricity in a body near it, an *vice versa*, the effect being greater as the distance diminishes. This power which electricity possesses of causing an opposite electrical state in its vicinity is called induction. When a body charged with either species of electricity is presented to a neutral one, its tendency, in consequence of the law of induction, is to disturb the electrical condition of the neutral body. The electrified body induces electricity contrary to its own in the adjacent part of the neutral one, and therefore an electrical state similar to its own in the remote part; hence the neutrality of the second body is destroyed by the action of the first, and the adjacent parts of the two, having now opposite electricities, will attract each other. The attraction between electrified and unelectrified substances is therefore merely a consequence of their altered state, resulting directly from the law of induction, and not an original law. The effects of induction depend upon the facility with which the equilibrium of the neutral state of a body can be overcome, a facility which is proportional to the conducting power of the body; consequently, the attraction exerted by an electrified substance upon another substance previously neutral will be

much more energetic if the latter be a conductor than if it be a non-conductor.

The law of electrical attraction and repulsion has been determined by suspending a needle of gum lac horizontally by a silk fibre, the needle carrying at one end a piece of electrified gold-leaf. A globe charged with the same, or with the opposite kind of electricity, when presented to the gold-leaf, will repel or attract it, and will therefore cause the needle to vibrate more or less rapidly according to the distance of the globe. A comparison of the number of oscillations performed in a given time at different distances, will determine the law of the variation of the electrical intensity, in the same manner that the force of gravitation is measured by the oscillations of the pendulum. Coulomb invented an instrument which balances the forces in question by the force of the torsion of a thread, which consequently measures their intensity. By this method he found that the intensity of the electrical attraction and repulsion varies inversely as the square of the distance. Since electricity can only be in equilibrio from the mutual repulsion of its particles, — which, according to these experiments, varies inversely as the square of the distance, — its distribution in different bodies depends upon the laws of mechanics, and therefore becomes a subject of analysis and calculation. The distribution of electricity has been so successfully determined by the analytical investigation of M. Poisson and Mr. Ivory, that all the computed phenomena have been confirmed by observation.

It is found by direct experiment that a metallic globe or cylinder contains the same quantity of electricity when hollow that it does when solid; therefore electricity is entirely confined to the surface of bodies, or if it does penetrate their substance, the depth is inappreciable; consequently the quantity bodies are capable of receiving does not follow the proportion of their bulk, but depends principally upon the extent of surface over which it is spread; so that the exterior may be positively or negatively electric while the interior is in a state of perfect neutrality.

Electricity of either kind may be accumulated to a great extent in insulated bodies, and as long as it is quiescent it occasions no sensible change in their properties, though it is spread over their surfaces in indefinitely thin layers. When restrained by the non-conducting power of the atmosphere, the tension or pressure exerted by the electric fluid against the air which opposes its escape is in the ratio compounded of the repulsive force of its own particles at the surface of the stratum of the fluid and of the thickness of that stratum; but as one of these elements is always proportional to the other, the total pressure on every point must be proportional to the square of the thickness. If this pressure be less than the coercive force of the air, the electricity is retained; but the instant it exceeds that force in any one point the electricity escapes, which it will do when the air is attenuated, or becomes saturated with moisture.

The power of retaining electricity depends also upon the shape of the body. It is most easily retained by a sphere, next to that by a spheriod, but it readily escapes from a point: and, on the contrary, a pointed object receives it with most facility. It appears from analysis that electricity, when in equilibrio, spreads itself in a thin stratum over the surface of a sphere, in consequence of the repulsion of its particles, which force is directed from the centre to the surface. In an oblong spheroid the intensity or thickness of the stratum of electricity at the extremities of the two axes is exactly in the proportion of the axes themselves; hence, when the ellipsoid is much elongated, the electricity becomes very feeble at the equator and powerful at the poles. A still greater difference in the intensities takes place in bodies of a cylindrical or prismatic form, and the more so in proportion as their length exceeds their breadth; therefore the electrical intensity is very powerful at a point, where nearly the whole electricity in the body will be concentrated.

A perfect conductor is not mechanically affected by the passage of electricity, if it be of sufficient size to carry off the whole; but it is shivered to pieces in an instant, if it be

too small to carry off the charge; this also happens to a bad conductor. In that case the physical change is generally a separation of the particles, though it may occasionally be attributed to chemical action, or expansion from the heat evolved during the passage of the fluid; but all these effects are in proportion to the obstacles opposed to the freedom of its course. The heat produced by the electric shock is intense, fusing metals, and even volatilizing substances, though it is only accompanied by light when the fluid is obstructed in its passage. Electrical light is perfectly similar to solar light in its composition; it seems to arise from the condensation of the air, during the rapid motion of electricity, and varies both in intensity and colour with the density of the atmosphere. Electricity is occasionally produced by pressure and fracture; several crystalline substances also become electric when heated, especially tourmaline, one end of which acquires positive, and the other negative electricity, while the intermediate part is neutral; but when broken through the middle, each fragment is found to possess positive electricity at one end, and negative at the other, like the entire crystal. Electricity is evolved by bodies passing from a liquid to a solid state, also by the production and condensation of vapour, which is consequently a great source of atmospheric electricity.

The atmosphere, when clear, is almost always positively electric; its electricity is stronger in winter than in summer, during the day than in the night. The intensity increases for two or three hours from the time of sunrise, then decreases towards the middle of the day, and again augments as the sun declines, till about the time of sunset, after which it diminishes, and continues feeble during the night. Atmospheric electricity arises from an evolution of the electric fluid during the evaporation that is so abundant at the surface of the earth; and clouds probably owe their existence, or at least their form, to it, for they consist of hollow vesicles of vapour coated with electricity; as the electricity is either entirely positive or negative, the vesicles repel each other,

which prevents them from uniting and falling down in rain. The friction of the surfaces of two strata of air moving in different directions, probably developes electricity; and if the strata be of different temperatures, a portion of the vapour they always contain will be deposited; the electricity evolved will be taken up by the vapour, and will cause it to assume the vesicular state constituting a cloud. A vast deal of electricity may be accumulated in this manner, which may either be positive or negative, and should two clouds charged with opposite kinds approach within a certain distance, the thickness of the coating of electricity will increase on the two sides of the clouds that are nearest to one another; and when the accumulation becomes so great as to overcome the coercive pressure of the atmosphere, a discharge takes place, which occasions a flash of lightning. The actual quantity of electricity in any one part of a cloud is extremely small; the intensity of the flash arises from the very great extent of surface occupied by the electricity, so that the clouds may be compared to enormous Leyden jars thinly coated with the electric fluid, which only acquires its intensity by its instantaneous condensation.

An interchange frequently takes place between the clouds and the earth, but on account of the extreme rapidity of lightning it is difficult to ascertain whether it goes from the clouds to the earth, or shoots upwards from the earth to the clouds, though there can be no doubt that it does both. M. Halvig measured the velocity of lightning by means of the camera lucida, and estimates that it is probably eight or ten miles in a second, or about forty times greater than that of sound; and M. Gay-Lussac has ascertained that a flash of lightning sometimes darts more than three miles at once in a straight line.

A person may be killed by lightning, although the explosion takes place at the distance of twenty miles, by what is called the back stroke. Suppose that the two extremities of a cloud highly charged with electricity hang down towards the earth, they will repel the electricity from the earth's sur-

face, if it be of the same kind with their own, and will attract the other kind; and if a discharge should suddenly take place at one end of the cloud, the equilibrium will instantly be restored by a flash at that point of the earth which is under the other.

The pure air, at all times negatively electric, becomes intensely so on the approach of rain, snow, wind, hail, or sleet, but it afterwards varies on opposite sides, and the transitions are very rapid on the approach of a thunder-storm. An insulated conductor then gives out such quantities of sparks that it is dangerous to approach it, as was fatally experienced by Professor Richman, at Petersburg, who was struck dead by a globe of fire from the extremity of a conductor, while making experiments on atmospheric electricity. There is no instance on record of an electric cloud being dispelled by a conducting rod silently withdrawing the electric fluid; yet it may mitigate the stroke, or render it harmless if it should come. Sir John Leslie observes, that the efficacy of conductors depends upon the rapidity with which they transmit the electric energy; and as copper is found to transmit the fluid twenty times faster than iron, and as iron conducts it 400,000,000 times more rapidly than water, which conveys it several thousands times faster than dry stone, copper conductors afford the best protection, especially if they expose a broad surface, since the electric fluid is conveyed chiefly along the exterior of bodies. The object of a conductor being to carry off the electricity in case of a stroke, and not to invite an enemy, it ought to project very little, if at all, above the building.

The aurora borealis is decidedly an electrical phenomenon, which takes place in the highest regions of the atmosphere, since it is visible at the same time from places very far distant from each other. It is somehow connected with the magnetic poles of the earth, but it has never been seen so far north as the pole of the earth's rotation, nor does it extend to low latitudes. It generally appears in the form of a luminous arch, stretching more or less from east to west, but

never from north to south; across the arch the coruscations are rapid, vivid, and of various colours. A similar phenomenon occurs in the high latitudes of the southern hemisphere. Mr. Faraday conjectures that the electric equilibrium of the earth is restored by means of the aurora conveying the electricity from the poles to the equator.

GALVANISM.

Galvanism is a peculiar kind of electricity, elicited by the force of chemical action, instead of friction. It is connected with one of the most brilliant periods of British science, from the splendid discoveries to which it led Sir Humphrey Davy; but it has acquired additional interest since it has proved, by the reciprocal action of galvanic and magnetic currents, that magnetism has no existence as a distinct or separate principle, but is only an effect of electricity: therefore, galvanism, as immediately connected with the theory of the earth and planets, forms a part of the physical account of their nature.

The disturbance of electric equilibrium, and a developement of electricity, invariably accompanies the chemical action of a fluid on metallic substances, and is most plentiful when that action occasions oxidation. Metals vary in the quantity of electricity afforded by their combination with oxygen; but the greatest abundance is developed by the oxidation of zinc by weak sulphuric acid; and in conformity with the law, that one kind of electricity cannot be evolved without an equal quantity of the other being brought into activity, it is found that the acid is positively, and the zinc negatively electric. It has not yet been ascertained why equilibrium is not restored by the contact of these two substances, which are both conductors, and in opposite electrical states; however, the electrical and chemical changes are so connected, that unless the equilibrium be restored, the action of the acid will go on languidly, or stop as soon as a certain quantity of

electricity is accumulated in the acid. The equilibrium, however, will be restored, and the action of the acid will be continuous, if a plate of copper be placed in contact with the zinc, both being partly immersed in the fluid; for the copper, not being acted upon by the acid, will serve as a conductor to convey the positive electricity from the acid to the zinc, and will at every instant restore the equilibrium, and then the oxidation of the zinc will go on rapidly. Thus three substances are concerned in forming a galvanic circuit, but it is indispensable that one of them be a fluid. The electricity so obtained will be very feeble, but it may be augmented by increasing the number of plates. In the common galvanic battery, the electricity which the fluid has acquired from the first plate of zinc exposed to its action, is taken up by the copper plate belonging to the second pair, and transferred to the second zinc plate with which it is connected. This second plate of zinc having thus acquired a larger portion of electricity than its natural share, communicates a larger quantity of electricity to the fluid in the second cell. This increased quantity is again transferred to the next pair of plates; and thus every succeeding alternation is productive of a further increase in the quantity of the electricity developed. This action, however, would stop unless a vent were given to the accumulated electricity, by establishing a communication between the positive and negative poles of the battery, by means of wires attached to the extreme plate at each end. When the wires are brought into contact, the galvanic circuit is completed, the electricities meet and neutralize each other, producing the shock and other electrical phenomena, and then the electric current continues to flow uninterruptedly in the circuit, as long as the chemical action lasts. The stream of positive electricity flows from the zinc to the copper, but as the battery ends in a zinc plate which communicates with the wire, the zinc end becomes the positive, and the copper the negative poles of a compound battery, which is exactly the reverse of what obtains in a single circuit.

Galvanic or voltaic, like common electricity, may either be considered to consist of two fluids passing in opposite directions through the circuit, the positive stream coming from the zinc, and the negative from the copper end of the battery; or, if the hypothesis of one fluid be adopted, the zinc end of the battery may be supposed to have an excess of electricity, and the copper end a deficiency.

Voltaic electricity is distinguished by two marked characters. Its intensity increases with the number of plates — its quantity with the extent of their surfaces. The most intense concentration of force is displayed by a numerous series of large plates, light and heat are copiously evolved, and chemical decomposition is accomplished with extraordinary energy; whereas, the electricity from one pair of plates is so feeble, whatever their size may be, that it gives no sign either of attraction or repulsion; and, even with a battery consisting of a very great number of plates, it is difficult to render the mutual attraction of its two wires sensible, though of opposite electricities.

The action of voltaic electricity differs materially from that of the ordinary kind. When a quantity of common electricity is accumulated, the restoration of equilibrium is attended by an instantaneous violent explosion, accompanied by the developement of light, heat, and sound. The concentrated power of the fluid forces its way through every obstacle, disrupting and destroying the cohesion of the particles of the bodies through which it passes, and occasionally increasing its destructive effects by the conversion of fluids into steam from the intensity of the momentary heat, as when trees are torn to pieces by a stroke of lightning: even the vivid light which marks the path of the electric fluid is probably owing to the sudden compression of the air and other particles of matter during the rapidity of its passage; but the instant equilibrium is restored by this energetic action, the whole is at an end. On the contrary, when an accumulation takes place in a voltaic battery, equilibrium is restored the moment the circuit is completed; but so far is the electric stream from

being exhausted, that it continues to flow silently and invisibly in an uninterrupted current supplied by a perpetual reproduction; and although its action on bodies is neither so sudden nor so intense as that of common electricity, yet it acquires such power from constant accumulation and continued action, that it ultimately surpasses the energy of the other. The two kinds of electricity differ in no circumstance more than in the developement of heat. Instead of a momentary evolution, which seems to arise from a forcible compression of the particles of matter during the passage of the common electric fluid, the circulation of the voltaic electricity is accompanied by a continued developement of heat, lasting as long as the circuit is complete, without producing either light or sound; and this appears to be its immediate direct effect, independent of mechanical action. Its intensity is greater than that of any heat that can be obtained by artificial means, so that it fuses substances which resist the action of the most powerful furnaces. The temperature of every part of a galvanic battery itself is raised during its activity.

When the battery is powerful, the luminous effects of galvanism are very brilliant; but considerable intensity is requisite to enable the electricity to force its way through the air on bringing the wires together from the opposite poles. Its transit is accompanied by light, and in consequence of the continuous supply of the fluid, sparks occur every time the contact of the wires is either broken or renewed. The most splendid artificial light known is produced by fixing pencils of charcoal at the extremities of the wires, and bringing them into contact. This light is the more remarkable as it appears to be independent of combustion, since the charcoal suffers no change, and likewise because it is equally vivid in such gases as do not contain oxygen. Though nearly as bright as solar light, it differs from it in possessing some of those rays of which the sunbeams are deficient, according to the experiments of M. Fraunhofer. Voltaic electricity is a powerful agent in chemical analysis; numerous instances might be given, but the decomposition of water is perhaps

the most simple and elegant. Suppose a glass tube filled with very pure water, and corked at both ends: if one of the wires of an active galvanic battery be made to pass through one cork, and the other through the other cork, into the water, so that the extremities of the two wires shall be opposite and about a quarter of an inch asunder, chemical action will immediately take place, and gas will continue to rise from the extremities of both wires till the water has vanished. If an electric spark be then sent through the tube, the water will re-appear. By arranging the experiments so as to have the gas given out by each wire separately, it is found that water consists of two parts of hydrogen and one of oxygen. The positive wire of the battery has a stronger affinity for oxygen than oxygen has for hydrogen; it consequently combines with the oxygen of the water, and sets the hydrogen free; but as the negative wire has a stronger affinity for hydrogen than hydrogen has for oxygen, it combines with the hydrogen of the water, and sets the oxygen free. If, therefore, an electric spark be sent through a mixture consisting of two parts of hydrogen and one of oxygen, the gases will combine and form water. The decomposition of the alkalies and earths by Sir Humphrey Davy, and all chemical changes produced by the electric fluid, are accomplished on the same principle; and it appears that, in general, combustible substances go to the negative wire, while oxygen is evolved at the positive. The powerful efficacy of voltaic electricity in chemical decomposition arises from the continuance of its action, and its agency appears to be most exerted on fluids and substances which, by conveying the electricity partially and imperfectly, impede its progress. But it is now proved to be as efficacious in the composition as in the decomposition or analysis of bodies.

It had been observed that, when metallic solutions are subjected to galvanic action, a deposition of metal, generally in the form of minute crystals, takes place on the negative wire: by extending this principle, and employing a very feeble voltaic action, M. Becquerel has succeeded in forming crys-

tals of a great proportion of the mineral substances precisely similar to those produced by nature. The electric state of metallic veins makes it possible that many natural crystals may have taken their form from the action of electricity bringing their ultimate particles, when in solution, within the narrow sphere of molecular attraction already mentioned as the great agent in the formation of solids. Both light and motion favour crystallization. Crystals which form in different liquids are generally more abundant on the side of the jar exposed to the light; and it is a well known fact that still water, cooled below 32°, starts into crystals of ice the instant it is agitated. Light and motion are intimately connected with electricity, which may therefore have some influence on the laws of aggregation; this is the more likely, as a feeble action is alone necessary, provided it be continued for a sufficient time. Crystals formed rapidly are generally imperfect and soft, and M. Becquerel found that even years of constant voltaic action were necessary for the crystallization of some of the hard substances. If this law be general, how many ages may be required for the formation of a diamond!

Several fish possess the faculty of producing electrical effects. The most remarkable are the gymnotus electricus, found in South America, and the torpedo, a species of ray, frequent in the Mediterranean. The absolute quantity of electricity brought into circulation by the torpedo is so great that it effects the decomposition of water, has power sufficient to make magnets, and gives very severe shocks; it is identical in kind with that of the galvanic battery, the electricity of the under surface of the fish being the same with the negative pole, and that in the upper surface the same with the positive pole: its manner of action is, however, somewhat different, for, although the evolution of the electricity is continued for a sensible time, it is interrupted, being communicated by a succession of discharges.

MAGNETISM.

In order to explain the other methods of exciting electricity, and the recent discoveries that have been made in that science, it is necessary to be acquainted with the general theory of magnetism, and also with the magnetism of the earth, the director of the mariner's compass, and his guide through the ocean. Its influence extends over every part of the earth's surface, but its action on the magnetic needle determines the poles of this great magnet, which by no means coincide with the poles of the earth's rotation. In consequence of their attraction and repulsion, a needle freely suspended, whether it be magnetic or not, only remains in equilibrio when in the magnetic meridan, that is, in the plane which passes through the north and south magnetic poles. There are places where the magnetic meridan coincides with the terrestrial meridian; in these a magnetic needle freely suspended points to the true north; but if it be carried successively to different places on the earth's surface, its direction will deviate sometimes to the east and sometimes to the west of north. Lines drawn on the globe, through all the places where the needle points due north and south, are called lines of no variation, and they are extremely complicated. The direction of the needle is not even constant in the same place, but changes in a few years according to a law not yet determined. In 1667, the line of no variation passed through London; from that time it has moved slowly, but irregularly, westward, and is now in North America. In the year 1819, Sir Edward Parry, in his voyage to discover the north-west passage round America, sailed near the magnetic pole; and in 1824, Captain Lyon, on an expedition for the same purpose, found that the magnetic pole was then situate in 63° 26′ 51″ north latitude, and in 80° 51′ 25″ west longitude. It appears, from later researches, that the law of terrestrial magnetism is of considerable complexity and the existence of more than

one magnetic pole in either hemisphere has been rendered highly probable; that there is one in Siberia seems to be decided by the recent observations of M. Hansteen, — it is in longitude 102° east of Greenwich, and a little to the north of the 60th degree of latitude: so that, by these data, the two magnetic poles in the northern hemisphere are about 180° distant from each other; but Captain Ross, who is just returned from a voyage in the polar seas, has ascertained that the American magnetic pole is in 70° 14′ north latitude, and 96° 40′ west longitude. The magnetic equator does not exactly coincide with the terrestrial equator; it appears to be an irregular curve inclined to the earth's equator at an angle of about 12°, and crossing it in at least three points in longitude 113° 14′ west, and 66° 46′ east of the meridian of Greenwich, and again somewhere between 156° 30′ of west longitude, and 116° east.

The needle is also subject to diurnal variations; in our latitudes it moves slowly eastward during the forenoon, and returns to its mean position about ten in the evening; it then deviates to the westward, and again returns to its mean position about ten in the morning. M. Kupffer of Casan, ascertained in the year 1831, that there is a nightly, as well as diurnal variation, depending, in his opinion, upon a variation in the magnetic equator.

A magnetic needle, suspended so as to be moveable only in the vertical plane, dips, or becomes more and more inclined to the horizon the nearer it is brought to the magnetic pole, and there becomes vertical. At the magnetic equator it is horizontal, and between these two positions it assumes every degree of inclination. Captain Lyon found that the dip in the latitude and longitude mentioned, very near the magnetic pole, was 86° 32′, and Captain Segelke determined it to be 69° 38′ at Woolwich in 1830. According to Captain Sabine, it appears to have been decreasing for the last fifty years at the rate of three minutes annually.

If a magnetised needle freely suspended, and at rest in the

magnetic meridian, be drawn any number of degrees from its position, it will make a certain number of oscillations before it resumes its state of rest. The intensity of the magnetic force is determined from these oscillations in the same manner that the intensity of the gravitating and electrical forces are known from the vibrations of the pendulum and the balance of torsion, and in all these cases it is proportional to the square of the number of oscillations performed in a given time ; consequently a comparison of the number of vibrations accomplished by the same needle, during the same time, in different parts of the earth's surface, will determine the variations in the magnetic action. By this method Humboldt and Rossel have discovered that the intensity of the magnetic force increases from the equator to the poles, where it is probably at its maximum. It appears to be doubled in the ascent from the equator to the western limits of Baffin's Bay. According to the magnetic observations of Professor Hansteen of Christiania, the magnetic intensity has been decreasing annually at Christiania, London, and Paris, at the rate of its 235th, 725th, and 1020th parts, respectively, which he attributes to the revolution of the Siberian magnetic pole. There is, however, so much uncertainty in the magnetic phenomena of the earth, that the results require to be continually corrected by new observations.

The inventor of the mariner's compass, like most of the early benefactors of mankind, is unknown ; it is even doubted which nation first made use of magnetic polarity to determine positions on the surface of the globe ; but it is said that a rude form of the compass was invented in Upper Asia, and conveyed thence by the Tartars to China, where the Jesuit missionaries found traces of this instrument having been employed as a guide to land travellers in very remote antiquity. From that the compass spread over the east, and was imported into Europe by the Crusaders, and its construction improved by an artist of Amalfi, on the coast of Calabria. It seems that the Romans and Chinese only employed eight

cardinal divisions, which the Germans successively bisected till there were thirty-two, and gave the points the names which they still bear.

The variation of the compass was unknown till Columbus, during his first voyage, observed that the needle declined from the meridian as he advanced across the Atlantic. The dip of the magnetic needle was first noticed by Robert Norman, in the year 1576.

Very delicate experiments have shown that all bodies are more or less susceptible of magnetism. Many of the gems give signs of it; cobalt, titanium, and nickel sometimes even possess the properties of attraction and repulsion; but the magnetic agency is most powerfully developed in iron, and in that particular ore of iron called the load-stone, which consists of the protoxide and the peroxide of iron, together with small portions of silica and alumina. A metal is often susceptible of magnetism if it only contains the 130,000th part of its weight of iron, a quantity too small to be detected by any mechanical test.

The bodies in question are naturally magnetic, but that property may be imparted by a variety of methods, as by friction with magnetic bodies, or juxtaposition to them, but none is more simple than percussion. A bar of hard steel, held in the direction of the dip, will become a magnet on receiving a few smart blows with a hammer on its upper extremity; and M. Hansteen has ascertained that every substance has magnetic poles when held in that position, whatever the materials may be of which it is composed.

One of the most distinguishing marks of magnetism is polarity, or the property a magnet possesses, when freely suspended, of spontaneously pointing nearly north and south, and always returning to that position when disturbed. Another property of a magnet is the attraction of unmagnetised iron. Both poles of a magnet attract iron, which in return attracts either pole of the magnet with an equal and contrary force. The magnetic intensity is most powerful at the poles, as may easily be seen by dipping the magnet into iron filings, which

will adhere abundantly to each pole, while scarcely any attach themselves to the intermediate parts. The action of the magnet on unmagnetised iron is confined to attraction, whereas the reciprocal agency of magnets is characterized by a repulsive as well as an attractive force, for a north pole repels a north pole, and a south repels a south pole: but a north and a south pole mutually attract one another, which proves that there are two distinct kinds of magnetic forces, directly opposite in their effects, though similar in their mode of action.

Induction is the power which a magnet possesses of exciting temporary or permanent magnetism in such bodies in its vicinity as are capable of receiving it. By this property the mere approach of a magnet renders iron or steel magnetic, the more powerfully the less the distance. When the north pole of a magnet is brought near to, and in the line with an unmagnetised iron bar, the bar acquires all the properties of a perfect magnet, the end next the north pole of the magnet becomes a south pole, while the remote end becomes a north pole. Exactly the reverse takes place when the south pole is presented to the bar; so that each pole of a magnet induces the opposite polarity in the adjacent end of the bar, and the same polarity in the remote extremity; consequently the nearest extremity of the bar is attracted, and the farther repelled; but as the action is greater on the adjacent than on the distant part, the resulting force is that of attraction. By induction, the iron bar not only acquires polarity, but the power of inducing magnetism in a third body; and although all these properties vanish from the iron as soon as the magnet is removed, a lasting increase of intensity is generally imparted to the magnet itself by the reaction of the temporary magnetism of the iron. Iron acquires magnetism more rapidly than steel, yet it loses it as quickly on the removal of the magnet, whereas the steel is impressed with a lasting polarity.

A certain time is requisite for the induction of magnetism, and it may be accelerated by any thing that excites a vibra-

tory motion in the particles of the steel, such as the smart stroke of a hammer, or heat succeeded by sudden cold. A steel bar may be converted into a magnet by the transmission of an electric discharge through it, and as its efficacy is the same in whatever direction the electricity passes, the magnetism arises from its mechanical operation exciting a vibration among the particles of the steel. It has been observed that the particles of iron easily resume their neutral state after induction, but those of steel resist the restoration of magnetic equilibrium, or a return to the neutral state: it is therefore evident, that any cause which removes or diminishes the resistance of the particles will tend to destroy the magnetism of the steel; consequently, the same mechanical means which develope magnetism will also destroy it. On that account, a steel bar may lose its magnetism by any mechanical concussion, such as by falling on a hard substance, a blow with a hammer, and heating to redness, which reduces the steel to the state of soft iron. The circumstances which determine whether it shall gain or lose being its position with respect to the magnetic equator, and the higher or lower intensity of its previous magnetic state.

Polarity of one kind only can exist in any portion of iron or steel, for in whatever manner the intensities of the two kinds of polarity may be diffused through a magnet, they exactly balance or compensate one another. The northern polarity is confined to one half of a magnet, and the southern to the other, and they are generally concentrated in or near the extremities of the bar. When a magnet is broken across its middle, each fragment is at once converted into a perfect magnet; the part which originally had a north pole, acquires a south pole at the fractured end, the part that originally had a south pole gets a north pole; and as far as mechanical division can be carried, it is found that each fragment, however small, is a perfect magnet.

A comparison of the number of vibrations accomplish by the same needle, during the same time, at different distances from a magnet, gives the law of magnetic intensity, which,

like every known force that emanates from a centre, follows the inverse ratio of the square of the distance, a law that is not affected by the intervention of any substance whatever between the magnet and the needle, provided that substance be not itself susceptible of magnetism. Induction and the reciprocal action of magnets are, therefore, subject to the laws of mechanics, but the composition and resolution of the forces are complicated, in consequence of four forces being constantly in activity, two in each magnet.

The phenomena of magnetism may be explained on the hypothesis of two extremely rare fluids pervading all the particles of iron, and incapable of leaving them. Whether the particles of these fluids are coincident with the molecules of the iron, or that they only fill the interstices between them, is unknown and immaterial; but it is certain that the sum of all the magnetic molecules, added to the sum of all the spaces between them, whether occupied by matter or not, must be equal to the whole volume of the magnetic body. When the two fluids in question are combined they are inert, so that the substances containing them show no signs of magnetism; but when separate they are active, the molecules of each of the fluids attracting those of the opposite kind, and repelling those of the same kind. The decomposition of the united fluids is accomplished by the inductive influence of either of the separate fluids; that is to say, a ferruginous body acquires polarity by the approach of either the south or north pole of a magnet. The electric fluids are confined to the surfaces of bodies, whereas the magnetic fluids pervade each molecule of the mass; besides, the electric fluid has a perpetual tendency to escape, and does escape, when not prevented by the coercive power of the surrounding air and other non-conducting bodies. Such a tendency does not exist in the magnetic fluids, which never quit the substance that contains them under any circumstances whatever; nor is any sensible quantity of either kind of polarity ever transferred from one part to another of the same piece of steel. It appears that the two magnetic fluids, when decomposed by the influence of mag-

netising forces, only undergo a displacement to an insensible degree within the body. The action of all particles so displaced upon a particle of the magnetic fluid in any particular situation, compose a resultant force, the intensity and direction of which it is the province of the analyst to determine. In this manner M. Poisson has proved that the result of the action of all the magnetic elements of a magnetised body is a force equivalent to the action of a very thin stratum covering the whole surface of a body, and consisting of the two fluids — the austral and the boreal, occupying different parts of it; or, in other words, the attractions and repulsions externally exerted by a magnet are exactly the same as if they proceeded from a very thin stratum of each fluid occupying the surface only, both fluids being in equal quantities, and so distributed that their total action upon all the points in the interior of the body are equal to nothing. Since the resulting force is the difference of the two polarities, its intensity must be greatly inferior to that of either.

It may be observed that, in addition to the forces already mentioned, there must be some coercive force analogous to friction which arrests the particles of both fluids, so as first to oppose the separation of the fluids, and then to prevent their reuniting. In soft iron the coercive force is either wanting or extremely feeble, since the iron is easily rendered magnetic by induction, and as easily loses its magnetism; whereas in steel the coercive force is extremely energetic, because it prevents the steel from acquiring the magnetic properties rapidly, and entirely hinders it from losing them when acquired. The feebleness of the coercive force in iron, and its energy in steel, with regard to the magnetic fluids, is perfectly analogous to the facility of transmission afforded to the electric fluids by non-electrics, and the resistance they experience in electrics. At every step the analogy between magnetism and electricity becomes more striking. The agency of attraction and repulsion is common to both, the positive and negative electricities are similar to the northern and southern polarities, and are governed by the same laws, namely, that

between like powers there is repulsion, and between unlike powers there is attraction; each of these four forces is capable of acting most enegetically when alone, but the electric equilibrium is restored by the union of the two electricities, and magnetic neutrality by the combination of the two polarities, thus respectively neutralizing each other when joined. All these forces vary inversely as the square of the distance, and consequently come under the same mechanical laws. A like analogy extends to magnetic and electrical induction. Iron and steel are in a state of equilibrium when the two magnetic polarities conceived to reside in them are equally diffused throughout the whole mass, so that they are altogether neutral. But this equilibrium is immediately disturbed on the approach of the pole of a magnet, which by induction transfers one kind of polarity to one end of the iron or steel bar, and the opposite kind to the other, — effects exactly similar to electrical induction. There is even a correspondence between the fracture of a magnet and that of an electric conductor; for if an oblong conductor be electrified by induction, its two extremities will have opposite electricities; and if in that state it be divided across the middle, the two portions, when removed to a distance from one another, will each retain the electricity that has been induced upon it. The analogy, however, does not extend to transference. A body may transfer a redundant quantity of positive or negative electricity to another, the one gaining at the expense of the other; but there is no instance of a body possessing only one kind of polarity. With this exception, there is such perfect correspondence between the theories of magnetic attractions and repulsions and electric forces in conducting bodies, that they not only are the same in principle, but are determined by the same formulæ. Experiment concurs with theory in proving the identity of these two unseen influences.

ELECTRO-MAGNETISM.

The disturbing effects of the aurora borealis and of lightning on the mariner's compass had been long known, but in the year 1819, M. Oersted, Professor of Natural Philosophy at Copenhagen, discovered that a current of voltaic electricity exerts a powerful influence on a magnetised needle, an observation which has given rise to the theory of electro-magnetism, the most interesting science of modern times, whether it be considered as leading us a step farther in generalization, by identifying two agencies hitherto referred to different causes, or as developing a new force unparalleled in the system of the world, which, overcoming the retardation from friction, and the obstacle of a resisting medium, maintains a perpetual motion, often vainly attempted, but which it seems altogether impossible to accomplish by means of any other force or combination of forces than the one in question.

When the two poles of a voltaic battery are connected by a metallic wire, so as to complete the circuit, the electricity flows without ceasing; and if a straight portion of that wire be placed parallel to, and horizontally above, a magnetised needle at rest in the magnetic meridian, but freely poised like the mariner's compass, the action of the electric current flowing through the wire will instantly cause the needle to change its position: its extremity will deviate from the north towards the east and west, according to the direction in which the current is flowing; and on reversing the direction of the current, the motion of the needle will be reversed also. The numerous experiments that have been made on the magnetic and electric fluids, as well as those on the various relative motions of a magnetic needle, under the influence of galvanic electricity, arising from all possible positions of the conducting wire, and every direction of the voltaic current, together with all the other phenomena of electro-magnetism, are ex-

plained by Dr. Roget in some excellent articles on these subjects in the Library of Useful Knowledge.

All the experiments tend to prove that the force emanating from the electric current, which produces such effects on the magnetic needle, acts at right angles to the current and is therefore unlike any force hitherto known. The action of all the forces in nature is directed in straight lines, as far as we know, for the curves described by the heavenly bodies result from the composition of two forces, whereas, that which is exerted by an electrical current upon either pole of a magnet has no tendency to cause the pole to approach or recede, but to rotate about it. If the stream of electricity be supposed to pass through the centre of a circle whose plane is perpendicular to the current, the direction of the force exerted by the electricity will always be in the tangent to the circle, or at right angles to its radius; consequently the tangential force of the electricity has a tendency to make the pole of a magnet move in a circle round the wire of the battery. Mr. Barlow has proved that the action of each particle of the electric fluid in the wire, on each particle of the magnetic fluid in the needle, varies inversely as the square of the distance.

Rotatory motion was suggested by Dr. Wollaston; Mr. Faraday was the first who actually succeeded in making the pole of a magnet rotate about a vertical conducting wire. In order to limit the action of the electricity to one pole, about two-thirds of a small magnet was immersed in mercury, the lower end being fastened by a thread to the bottom of the vessel containing the mercury. When the magnet was thus floating almost vertically with its north pole above the surface, a current of positive electricity was made to descend perpendicularly through a wire touching the mercury, and immediately the magnet began to rotate from left to right about the wire. As the force is uniform, the rotation was accelerated till the tangential force was balanced by the resistance of the mercury, when it became constant. Under the same cir-

cumstances, the south pole of the magnet rotates from right to left. It is evident from this experiment that the wire may also be made to perform a rotation round the magnet, since the action of the current of electricity on the pole of the magnet must necessarily be accompanied by a corresponding reaction of the pole of the magnet on the electricity in the wire. This experiment has been accomplished by a vast number of contrivances, and even a small battery, consisting of two plates, has performed the rotation. Mr. Faraday produced both motions at the same time in a vessel containing mercury; the wire and the magnet revolved in one direction about a common centre of motion, each following the other.

The next step was to make a magnet and also a cylinder revolve about their own axes, which they do with great rapidity. Mercury has been made to rotate by means of voltaic electricity, and Professor Ritchie has exhibited in the Royal Institution the singular spectacle of the rotation of water by the same means, while the vessel containing it remained stationary. The water was in a hollow double cylinder of glass, and on being made the conductor of electricity, was observed to revolve in a regular vortex, changing its direction as the poles of the battery were alternately reversed. Professor Ritchie found that all the different conductors hitherto tried by him, such as water, charcoal, &c. give the same electro-magnetic results, when transmitting the same quantity of electricity, and that they deflect the magnetic needle in an equal degree when their respective axes of conduction are at the same distance from it. But one of the most extraordinary effects of the new force is exhibited by coiling a copper wire, so as to form a helix or corkscrew, and connecting the extremities of the wires with the poles of a galvanic battery. If a magnetised steel bar or needle be placed within the screw, so as to rest upon the lower and interior part, the instant a current of electricity is sent through the wire of the helix, the steel bar starts up by the influence of this invisible power, and remains suspended in the air in opposition to the force of gravitation. The effect of the electro-magnetic

power exerted by each turn of the wire is to urge the north pole of the magnet in one direction, and the south pole in the other; the force thus exerted is multiplied in degree and increased in extent by each repetition of the turns of the wire, and in consequence of these opposing forces the bar remains suspended. This helix has all the properties of a magnet while the electrical current is flowing through it, and may be substituted for one in almost every experiment. It acts as if it had a north pole at one extremity and a south pole at the other, and is attracted and repelled by the poles of a magnet exactly as if it were one itself. All these effects depend upon the course of the electricity, that is, on the direction of the turns of the screw, according as they are from right to left, or from left to right, being in the one case exactly the contrary of what it is in the other.

The effects of electricity in motion on magnets are not only precisely the same as the reciprocal action of magnetised bodies, but its influence in inducing magetism in unmagnetised iron and steel is also the same with magnetic induction. The term induction, when applied to electric currents, expresses the power which these currents possess of inducing any particular state upon matter in their immediate neighbourhood, otherwise neutral or indifferent. For example, the connecting wire of a galvanic battery holds iron filings suspended like an artificial magnet, as long as the current continues to flow through it; and the most powerful temporary magnets that have been made are obtained by bending a thick cylinder of soft iron into the form of a horseshoe, and surrounded it with a coil of thick copper wire covered with silk, to prevent communication between its parts. When this wire forms part of a galvanic circuit, the iron becomes so highly magnetic, that a temporary magnet of this kind made by Professor Henry* of the Albany Academy, in the United States, sustained nearly a ton weight. The iron loses its magnetic power the instant the electricity ceases to circu-

* Now of Princeton College, New Jersey.

late, and acquires it again as instantaneously when the circuit is renewed. Steel needles are rendered permanently magnetic by electrical induction; the effect is produced in a moment, and as readily by juxtaposition as by contact; the nature of the poles depends upon the direction of the current, and the intensity is proportional to the quantity of electricity.

It appears from what precedes, that the principle and characteristic phenomena of the electro-magnetic science are, the evolution of a tangential and rotatory force exerted between a conducting body and a magnet; and the transverse induction of magnetism by the conducting body in such substances as are susceptible of it.

The action of an electric current causes a deviation of the compass from the plane of the magnetic meridian. In proportion as the needle recedes from the meridian, the intensity of the force of terrestrial magnetism increases, while at the same time the electro-magnetic force diminishes; the number of degrees at which the needle stops, and which mark where the equilibrium between these two forces takes place, will indicate the intensity of the galvanic current. The galvanometer, constructed upon this principle, is employed to measure the intensity of galvanic currents collected and conveyed to it by wires. This instument is rendered much more sensible by neutralizing the effects of the earth's magnetism on the needle, which is accomplished by placing a second magnetised needle so as to counteract the action of the earth on the first, a precaution requisite in all delicate magnetical experiments.

ELECTRO-DYNAMICS.

The science of electro-magnetism which has been under consideration, and must render the name of M. Oersted ever memorable, relates to the reciprocal action of electrical and magnetic currents. M. Ampère, by discovering the mutual

action of electrical currents on one another, has added a new branch to the subject, to which he has given the name of electro-dynamics.

When electric currents are passing through two conducting wires so suspended or supported as to be capable of moving both towards and from one another, they show mutual attraction or repulsion, according as the currents are flowing in the same or in contrary directions; the phenomena varying with the relative inclinations and positions of the streams of electricity. It appears that the mutual action of such currents, whether they flow in the same or in contrary directions, whether they be parallel, perpendicular, diverging, converging, circular or heliacal, all produce different kinds of motion, in a conducting wire, both rectilineal and circular, and also the rotation of a wire helix, such as that described and now called an electro-dynamic cylinder on account of some improvements in its construction; and as the hypothesis of a force varying inversely as the square of the distance accords perfectly with all the observed phenomena, these motions come under the same laws of dynamics and analysis as any other branch of physics.

The theory of electro-dynamics, as well as actual experiment, confirms the identity between the agencies of electro-dynamics cylinders, or helices, and magnets. The law of the reciprocal action of a cylinder and an electric current is precisely the same, and all the experiments that can be performed with the cylinder might be accomplished with a magnet. It has already been observed that the two extremities of an electro-dynamic cylinder or helix exhibit all the properties possessed by the poles of a magnet; that end in which the current of positive electricity is moving in a direction similar to the motion of the hands of a watch, acting as a south pole, and the other end, in which the current is flowing in a contrary direction, exhibiting northern polarity. In conformity with this resemblance, electro-dynamics cylinders act on each other precisely as if they were magnets, during the time the electricity is flowing through them.

The phenomena marks a very decided difference between the action of electricity in motion or at rest, that is, between voltaic and common electricity; the laws they follow are in many respects of an entirely different nature. Since voltaic electricity flows perpetually, it cannot be accumulated, and consequently has no tension or tendency to escape from the wires which conduct it. Nor do these wires either attract or repel light bodies in their vicinity, whereas ordinary electricity can be accumulated in insulated bodies to a great degree, and in that state of rest the tendency to escape is proportional to the quantity accumulated and the resistance it meets with. In ordinary electricity, the law of action is, that dissimilar electricities attract, and similar electricities repel one another.

In voltaic electricity, on the contrary, similar currents, or such as are moving in the same direction, attract one another, while a mutual repulsion is exerted between dissimilar currents, or such as flow in opposite directions. The common electricity escapes when the pressure is removed, but the electro-dynamical effects are the same whether the conductors be in air or in vacuo.

Although the effects produced by a current of electricity depend upon the celerity of its motion, the velocity with which it moves through a conducting wire is unknown. We are equally ignorant whether it be uniform or varied, but the method of transmission has a marked influence on the results; for when it flows without intermission, it occasions a deviation in the magnetic needle, but it has no effect whatever when its motion is discontinuous or interrupted, like the current produced by the common electrical machine when a communication is made between the positive and negative conductors.

M. Ampère has established a theory of electro-magnetism suggested by the analogy between electro-dynamic cylinders and magnets, founded upon the reciprocal attraction of electric currents, to which all the phenomena of magnetism and electro-magnetism may be reduced, by assuming that the magnetic properties which bodies possess derive these pro-

perties from currents of electricity circulating about every part in one uniform direction. It has been observed that, although every particle of a magnet possess like properties with the whole, yet the general effect is the same as if the magnetic properties were confined to the surface; consequently the internal electro-currents must compensate one another, and therefore the magnetism of a body is supposed to arise from a superficial current of electricity constantly circulating in a direction perpendicular to the axis of the magnet; so that the reciprocal action of magnets, and all the phenomena of electro-magnetism, are reduced to the action and reaction of superficial currents of electricity acting at right angles to the direction of the currents. Notwithstanding some experiments made by M. Ampère to elucidate the subject, there is still an uncertainty in the theory of the induction of magnetism by an electric current in a body near it; for it does not appear, whether electric currents which did not previously exist are actually produced by induction, or if its effects be only to give one uniform direction to the infinite number of electric currents previously existing in the particles of the body, and thus rendering them capable of exhibiting magnetic phenomena, in the same manner as polarization reduces those undulations of light to one plane which had previously been performed in every plane. Possibly both may be combined in producing the effect; for the action of an electric current may not only give a common direction to those already existing, but may also increase their intensity. However that may be, by assuming that the attraction and repulsion of the elementary portions of electric currents vary inversely as the square of the distance, the action being at right angles to the direction of the current, it is found that the attraction and repulsion of a current of indefinite length on the elementary portion of a parallel current at any distance from it, is in the simple ratio of the shortest distance between them; consequently the reciprocal action of electric currents is reduced to the composition and resolution of forces, so that the phenomena of electro-magnetism are brought under the laws of dynamics by the theory of Ampère.

MAGNETO-ELECTRICITY.

From the law of action and reaction being equal and contrary, it might be expected that, as electricity powerfully affects magnets, so, conversely, magnetism ought to produce electrical phenomena. By proving this very important fact from a series of highly interesting and ingenious experiments, Mr. Faraday has added another branch to the science, which he has named magneto-electricity. A great quantity of copper wire was coiled in the form of a helix round one half of a ring of soft iron, and connected with a galvanic battery, while a similar helix connected with a galvanometer was wound round the other half of the ring, but not touching the first helix. As soon as contact was made with the battery, the needle of the galvanometer was deflected, but the action was transitory, for when the contact was continued the needle returned to its usual position, and was not affected by the continual flow of the electricity through the wire connected with the battery. As soon, however, as the contact was broken, the needle of the galvanometer was again deflected, but in the contrary direction. Similar effects were produced by an apparatus consisting of two helices of copper wire coiled round a block of wood, instead of iron, from which Mr. Faraday infers that the electric current passing from the battery through one wire induces a similar current through the other wire, but only at the instant of contact, and that a momentary current is induced in a contrary direction when the passage of the electricity is suddenly interrupted. These brief currents or waves of electricity were found to be capable of magnetising needles, or passing through a small extent of fluid, and when charcoal points were interposed in the current of the induced helix, a minute spark was perceived as often as the contacts were made or broken, but neither chemical action nor any other electric effects were obtained. A deviation of the needle of the galvanometer took place when

common magnets were employed instead of the voltaic current; so that magnetic and electric fluids are identical in their effects in this interesting experiment. Again when a helix formed of 220 feet of copper wire, into which a cylinder of soft iron was introduced, was placed between the north and south poles of two bar magnets, and connected with the galvanometer by means of wires from each extremity, as often as the magnets were brought into contact with the iron cylinder, it became magnetic by induction, and produced a deflection in the needle of the galvanometer. On continuing the contact, the needle resumed its natural position, and when the contact was broken, the deflection took place in the opposite direction; when the magnetic contacts were reversed, the deflection was reversed also. With strong magnets, so powerful was the action, that the needle of the galvanometer whirled round several times successively; and similar effects were produced by the mere approximation or removal of the helix to the poles of the magnets. Thus magnets produce the very same effects on the galvanometer that electricity does. Though at that time no chemical decomposition was effected by these momentary currents which emanated from the magnets, they agitated the limbs of a frog, and Mr. Faraday justly observes, that 'an agent which is conducted along metallic wires in the manner described, which, whilst so passing, possesses the peculiar magnetic actions and force of a current of electricity, which can agitate and convulse the limbs of a frog, and which finally can produce a spark by its discharge through charcoal, can only be electricity.' Hence it appears that electrical currents are evolved by magnets, which produce the same phenomena with the electrical currents from the voltaic battery; they, however, differ materially in this respect — that time is required for the exercise of the magneto-electric induction, whereas volta-electric induction, is instantaneous.

After Mr. Faraday had proved the identity of the magnetic and electric fluids by producing the spark, heating metallic wires, and accomplishing chemical decomposition, it

was easy to increase these effects by more powerful magnets and other arrangements. The following apparatus is now in use, which is in effect a battery, where the agent is the magnetic, instead of the voltaic fluid, or in other words, electricity.

A very powerful horseshoe magnet, formed of twelve steel plates in close approximation, is placed in a horizontal position. An armature consisting of a bar of the purest soft iron has each of its ends bent at right angles, so that the faces of those ends may be brought directly opposite and close to the poles of the magnet when required. Two series of copper wires — covered with silk, in order to insulate them — are wound round the bar of soft iron as compound helices. The extremities of these wires, having the same direction, are in metallic connexion with a circular disc, which dips into a cup of mercury, while the ends of the wires in the opposite direction are soldered to a projecting screw-piece, which carries a slip of copper with two opposite points. The steel magnet is stationary; but when the armature, together with its appendages, is made to rotate horizontally, the edge of the disc always remains immersed in the mercury, while the points of the copper slip alternately dip in it and rise above it. By the ordinary laws of induction, the armature becomes a temporary magnet while its bent ends are opposite the poles of the steel magnet, and ceases to be magnetic when they are at right angles to them. It imparts its temporary magnetism to the helices which concentrate it; and while one set conveys a current to the disc, the other set conducts the opposite current to the copper slip. But as the edge of the revolving disc is always immersed in the mercury, one set of wires is constantly maintained in contact with it, and the circuit is only completed when a point of the copper slip dips in the mercury also; but the circuit is broken the moment that point rises above it. Thus, by the rotation of the armature, the circuit is alternately broken and renewed; and as it is only at these moments that electric action is manifested, a brilliant spark takes place every time the copper point

touches the surface of the mercury. Platina wire is ignited, shocks smart enough to be disagreeable are given, and water is decomposed with astonishing rapidity, by the same means, which proves beyond a doubt the identity of the magnetic and electric agencies, and places Mr. Faraday, whose experiments established the principle, in the first rank of experimental philosophers.

M. Arago discovered an entirely new source of magnetism in rotatory motion. If a circular plate of copper be made to revolve immediately above or below a magnetic needle or magnet, suspended in such a manner that the needle may rotate in a plane parallel to that of the copper plate, the magnet tends to follow the circumvolution of the plate; or if the magnet revolves, the plate tends to follow its motion; and so powerful is the effect, that magnets and plates of many pounds weight have been carried round. This is quite independent of the motion of the air, since it is the same when a pane of glass is interposed between the magnet and the copper. When the magnet and the plate are at rest, not the smallest effect, attractive, repulsive, or of any kind, can be perceived between them. In describing this phenomenon, M. Arago states that it takes place not only with metals, but with all substances, solids, liquids, and even gases, although the intensity depends upon the kind of substance in motion. Experiments recently made by Mr. Faraday explain this singular action. A plate of copper, twelve inches in diameter and one-fifth of an inch thick, was placed between the poles of a powerful horseshoe magnet, and connected at certain points with a galvanometer by copper wires. When the plate was at rest no effect was produced, but as soon as the plate was made to revolve rapidly, the galvanometer needle was deflected sometimes as much as 90°, and by a uniform rotation, the deflection was

constantly maintained at 45°. When the motion of the copper plate was reversed, the needle was deflected in the contrary direction, and thus a permanent current of electricity was evolved by an ordinary magnet. The intensity of the electricity collected by the wires, and conveyed by them to the galvanometer, varied with the position of the plate relatively to the poles of the magnet.

The motion of the electricity in the copper plate may be conceived, by considering, that merely from moving a single wire like the spoke of a wheel before a magnetic pole, a current of electricity tends to flow through it from one end to the other; hence, if a wheel be constructed of a great many such spokes, and revolved near the pole of a magnet in the manner of the copper disc, each radius or spoke will tend to have a current produced in it as it passes the pole. Now as the circular plate is nothing more than an infinite number of radii or spokes in contact, the currents will flow in the direction of the radii if a channel be open for their return, and in a continuous plate that channel is afforded by the lateral portions on each side of the particular radius close to the magnetic pole. This hypothesis is confirmed by observation, for the currents of positive electricity set from the centre to the circumference, and the negative from the circumference to the centre, and vice versa, according to the position of the magnet poles and the direction of rotation. So that a collecting wire at the centre of the copper plate conveys positive electricity to the galvanometer in one case, and negative in another; that collected by a conducting wire in contact with the circumference of the plate is always the opposite of the electricity conveyed from the centre. It is evident that when the plate and magnet are both at rest, no effect takes place, since the electric currents which cause the deflection of the galvanometer cease altogether. The same phenomena may be produced by electro-magnets. The effects are the same when the magnet rotates and the plate remains at rest. When the magnet revolves uniformly about its own axis, electricity

of the same kind is collected at its poles, and the opposite electricity at its equator.

The phenomena which takes place in M. Arago's experiments may be explained on this principle, for when both the copper plate and the magnet are revolving, the action of the electric current, induced in the plate by the magnet in consequence of their relative motion, tends continually to diminish that relative motion; that is, to bring the moving bodies into a state of relative rest, so that if one be made to revolve by an extraneous force, the other will tend to revolve about it in the same direction, and with the same velocity.

When a plate of iron, or of any substance capable of being made either a temporary or permanent magnet, revolves between the poles of a magnet, it is found that dissimilar poles on opposite sides of the plate neutralize each other's effects, so that no electricity is evolved, while similar poles on each side of the revolving plate increase the quantity of electricity, and a single pole end-on is sufficient. But when copper, and substances not sensible to ordinary magnetic impressions, revolve, similar poles on opposite sides of the plate neutralize each other, dissimilar poles on each side exalt the action: and a single pole at the edge of the revolving plate, or end-on, does nothing. This forms a test for distinguishing the ordinary magnetic force from that produced by rotation. If unlike poles, that is a north and south pole, produce more effect than one pole, the force will be due to electric currents; if similar poles produce more effect than one, than the power is not electric. These investigations show that there are really very few bodies magnetic in the manner of iron. Mr. Faraday therefore arranges substances in three classes, with regard to their relation to magnets. Those affected by the magnet when at rest like iron, steel, and nickel, which possess ordinary magnetic properties; those affected when in motion, in which electric currents are evolved by the inductive force of the magnet, such as copper; and lastly, those which are perfectly indifferent to the magnet, whether at rest or in motion.

It has already been observed, that three bodies are requisite to form a galvanic circuit, one of which must be fluid; but in 1822, Professor Seebeck of Berlin, discovered that electric currents may be produced by the partial application of heat to a circuit formed of two solid conductors. For example, when a semicircle of bismuth, joined to a semicircle of antimony, so as to form a ring, is heated at one of the junctions by a lamp, a current of electricity flows through the circuit from the antimony to the bismuth, and such thermo-electric currents produce all the electro-magnetic effects. A compass needle placed either within or without the circuit, and at a small distance from it, is deflected from its natural position, in a direction corresponding to the way in which the electricity is flowing. If such a ring be suspended so as to move easily in any direction, it will obey the action of a magnet brought near it, and may even be made to revolve. According to the researches of M. Nobili, the same substance unequally heated, exhibits electrical currents. The experiments of Professor Cumming show that the mutual action of a magnet and a thermo-electric current, is subject to the same laws as those of magnets and galvanic currents, consequently all the phenomena of repulsion, attraction, and rotation may be exhibited by a thermo-electric current. It is, however, so feeble, that neither heat, the spark, nor chemical action have been observed, nor can repulsion, attraction of light substances at sensible distances, or any other effects of tension, be perceived.

In all the experiments hitherto described, artificial magnets alone were used, but it is obvious that the magnetism of the terrestrial spheroid which has so powerful an influence on the mariner's compass, must also effect electrical currents. It consequently appears that a piece of copper wire bent into a rec-

tangle, and free to revolve on a vertical axis, arranges itself with its plane at right angles to the magnetic meridian, as soon as a stream of electricity is sent through it. Under the same circumstances a similiar rectangle, suspended on a horizontal axis at right angles to the magnetic meridian, assumes the same inclination with the dipping needle. So that terrestrial magnetism has the same influence on electrical currents as an artificial magnet. But the magnetic action of the earth also induces electric currents. When a hollow helix of copper wire, whose extremities are connected with the galvanometer, is placed in the magnetic dip, and suddenly inverted several times, accommodating the motion to the oscillations of the needle, the latter is soon made to vibrate through an arc of 80° or 90°. Hence it is evident, that whatever may be the cause of terrestrial magnetism, it produces currents of electricity by its direct inductive power upon a metal not capable of exhibiting any of the ordinary magnetic properties. The action on the galvanometer is much greater when a cylinder of soft iron is inserted into the helix, and the same results follow the simple introduction of the iron cylinder into, or removal out of the helix. These effects arise from the iron being made a temporary magnet by the inductive action of terrestrial magnetism, for a piece of iron, such as a poker, becomes a magnet for the time, when placed in the line of the magnetic dip.

M. Biot has formed a theory of terrestrial magnetism upon the observations of M. de Humboldt as data. Assuming that the action of the two opposite magnetic poles of the earth upon any point is inversely as the square of the distance, he obtains a general expression for the direction of the magnetic needle, depending upon the distance between the north and south magnetic poles; so that if one of these quantities varies, the corresponding variation of the other will be known. By making the distance between the poles vary, and comparing the resulting direction of the needle with the observations of M. de Humboldt, he found that the nearer the poles are supposed to approach one to another, the more did the computed

and observed results agree; and when the poles were assumed to coincide, or nearly so, the difference between theory and observation was the least possible. It is evident, therefore, that the earth does not act as if it were a permanently magnetic body, the distinguishing characteristic of which is, to have two poles at a distance from one another. Mr. Barlow has investigated this subject with much skill and success. He first proved that the magnetic power of an iron sphere resides in its surface; he then inquired what the superficial action of an iron sphere in a state of transient magnetic induction, on a magnetised needle, would be, if insulated from the influence of terrestrial magnetism. The results obtained, corroborated by the profound analysis of M. Poisson, on the hypothesis of the two poles being indefinitely near the centre of the sphere, are identical with those obtained by M. Biot for the earth from M. de Humboldt's observations. Whence it follows, that the laws of terrestrial magnetism deduced from the formulæ of M. Biot, are inconsistent with those which belong to a permanent magnet, but that they are perfectly accordant with those belonging to a body in a state of transient magnetic induction. It appears, therefore, that the earth is to be considered as only transiently magnetic by induction, and not a real magnet. Mr. Barlow has rendered this extremely probable by forming a wooden globe, with grooves admitting of a copper wire being coiled round it parallel to the equator from pole to pole. When a current of electricity was sent through the wire, a magnetic needle suspended above the globe, and neutralized from the influence of the earth's magnetism, exhibited all the phenomena of the dipping and variation needles, according to its positions with regard to the wooden globe. As there can be no doubt that the same phenomena would be exhibited by currents of thermo, instead of voltaic, electricity, if the grooves of the wooden globe were filled by rings constituted of two metals, it seems highly probable that the heat of the sun may be the great agent in developing electric currents in or near the surface of the earth, by its action upon the substances of which the

globe is composed, and, by the changes in its intensity, may occasion the diurnal variation of the compass and the other vicissitudes in terrestrial magnetism evinced by the disturbance in the direction of the magnetic lines, in the same manner as it influences the parallelism of the isothermal lines. That such currents do exist in metalliferous veins appears from the experiments of Mr. Robert Fox in the Cornish copper-mines. However, it is probable that the secular and periodic disturbances in the magnetic force are occasioned by a variety of combining circumstances. Among others, M. Biot mentions the vicinity of mountain chains to the place of observation, and still more the action of extensive volcanic fires, which change the chemical state of the terrestrial surface, they themselves varying from age to age, some becoming extinct, while others burst into activity.

It is moreover probable that terrestrial magnetism may be owing, to a certain extent, to the earth's rotation. Mr. Faraday has proved that all the phenomena of revolving plates may be produced by the inductive action of the earth's magnetism alone. If a copper plate be connected with a galvanometer by two copper wires, one from the centre and another from the circumference, in order to collect and convey the electricity, it is found that, when the plate revolves in a plane passing through the line of the dip, the galvanometer is not affected; but as soon as the plate is inclined to that plane, electricity begins to be developed by its rotation; it becomes more powerful as the inclination increases, and arrives at a maximum when the plate revolves at right angles to the line of the dip. When the revolution is in the same direction with that of the hands of a watch, the current of electricity flows from its centre to the circumference; and when the rotation is in the opposite direction, the current sets the contrary way. The greatest deviation of the galvanometer, amounted to 50° or 60°, when the direction of the rotation was accommodated to the oscillations of the needle. Thus a copper plate, revolving in a plane at right angles to the line of the dip, forms a new electrical machine, differing from the common plate-

glass machine, by the material of which it is composed being the most perfect non-conductor; besides, insulation, which is essential in the glass machine, is fatal in the copper one. The quantity of electricity evolved by the metal does not appear to be inferior to that developed by the glass, though very different in intensity.

From the experiments of Mr. Faraday, and also from theory, it is possible that the rotation of the earth may produce electric currents in its own mass. In that case, they would flow superficially in the meridians, and if collectors could be applied at the equator and poles, as in the revolving plate, negative electricity would be collected at the equator, and positive at the poles; but without something equivalent to conductors to complete the circuit, these currents could not exist.

Since the motion, not only of metals but even of fluids, when under the influence of powerful magnets, evolves electricity, it is probable that the gulf stream may exert a sensible influence upon the forms of the lines of magnetic variation, in consequence of electric currents moving across it, by the electro-magnetic induction of the earth. Even a ship passing over the surface of the water, in northern or southern latitudes, ought to have electric currents running directly across the line of her motion. Mr. Faraday observes, that such is the facility with which electricity is evolved by the earth's magnetism, that scarcely any piece of metal can be moved in contact with others without a developement of it, and that consequently, among the arrangements of steam engines and metallic machinery, curious electro-magnetic combinations probably exist, which have never yet been noticed.

What magnetic properties the sun and planets may have, it is impossible to conjecture, although their rotation might lead us to infer that they are similar to the earth in this respect. According to the observations of M. M. Biot and Gay-Lussac, during their aërostatic expedition, the magnetic action is not confined to the surface of the earth, but extends into space. A decrease in its intensity was perceptible, and as it

most likely follows the ratio of the inverse square of the distance, it must extend indefinitely. It is probable that the moon has become highly magnetic by induction, in consequence of her proximity to the earth, and because her greatest diameter always points towards it. Should the magnetic, like the gravitating force, extend through space, the induction of the sun, moon, and planets must occasion perpetual vibrations in the intensity of terrestrial magnetism, by the continual changes in their relative positions.

In the brief sketch that has been given of the five kinds of electricity, those points of resemblance have been pointed out which are characteristic of one individual power; but as many anomalies have been lately removed, and the identity of the different kinds placed beyond a doubt, by Mr. Faraday, it may be satisfactory to take a summary view of the various coincidences in their modes of action on which their identity has been so ably and completely established by that great electrician.

The points of comparison are attraction and repulsion at sensible distances, discharge from points through air, the heating power, magnetic influence, chemical decomposition, action on the human frame, and lastly the spark.

Attraction and repulsion at sensible distances, which are so eminently characteristic of ordinary electricity, and in a lesser degree, also, of the voltaic and magnetic currents, have not been perceived in either the thermo or animal electricities, not on account of difference of kind, but entirely owing to inferiority in tension; for even the ordinary electricity, when much reduced in quantity and intensity, is incapable of exhibiting these phenomena.

Ordinary electricity is readily discharged from points through air, but Mr. Faraday found that no sensible effect took place from a battery consisting of 140 double plates, either through air or in the exhausted receiver of an air-pump, the tests of the discharge being the electrometer and chemical action, — a circumstance entirely owing to the small degree of tension, for an enormous quantity of electricity is required

to make these effects sensible, and for that reason they cannot be expected from the other kinds, which are much inferior in degree. Common electricity passes easily through rarefied and hot air, and also through flame. Mr. Faraday effected chemical decomposition and a deflection of the galvanometer by the transmission of voltaic electricity through heated air, and observes that these experiments are only cases of the discharge which takes place through air between the charcoal terminations of the poles of a powerful battery when they are gradually separated after contact—for the air is then heated; and Sir Humphry Davy mentions that, with the original voltaic apparatus at the Royal Institution, the discharge passed through four inches of air; that, in the exhausted receiver of an air pump, the electricity would strike through nearly half an inch of space, and that the combined effects of rarefaction and heat were such, upon the included air, as to enable it to conduct the electricity through a space of six or seven inches. A Leyden jar may be instantaneously charged with voltaic, and also with magneto-electricity — another proof of their tension. Such effects cannot be obtained from the other kinds, on account of their weakness only.

The heating powers of ordinary and voltaic electricity have long been known, but the world is indebted to Mr. Faraday for the wonderful discovery of the heating power of the magnetic fluid: there is no indication of heat either from the animal or thermo-electricities. All the kinds of electricity have strong magnetic powers, those of the voltaic fluid are highly exalted, and the existence of the magneto and thermo-electricities was discovered by their magnetic influence alone. The needle has been deflected by all in the same manner, and, with the exception of thermo-electricity, magnets have been made by all according to the same laws. Ordinary electricity was long supposed incapable of deflecting the needle, and it required all Mr. Faraday's ingenuity to produce that effect. He has, however, proved that, in this respect, also, ordinary electricity agrees with voltaic, but that time must be allowed for its action. It deflected the needle, whe-

ther the current was sent through rarefied air, water, or wire. Numerous chemical decompositions have been effected by ordinary and voltaic electricity, according to the same laws and modes of arrangement. Dr. Davy decomposed water by the electricity of the torpedo, — Mr. Faraday accomplished its decomposition, and Dr. Ritchie its composition by means of magnetic action; but the chemical effects of the thermo-electricity have not yet been observed. The electric and galvanic shock, the flash in the eyes, and the sensation on the tongue, are well known. All these effects are produced by magneto-electricity, even to a painful degree. The torpedo and gymnotus electricus give severe shocks, and the limbs of a frog have been convulsed by thermo-electricity. The last point of comparison is the spark, which is already mentioned as common to the ordinary, voltaic, and magnetic fluids; and although it has not yet been seen from the thermo and animal electricities, there can be no doubt that it is only on account of their feebleness. Indeed, the conclusion drawn by Mr. Faraday is, that the five kinds of electricity are identical, and that the differences of intensity and quantity are quite sufficient to account for what were supposed to be their distinctive qualities. He has given still greater assurance of their identity by showing that the magnetic force and the chemical action of electricity are in direct proportion to the absolute quantity of the fluid which passes through the galvanometer, whatever its intensity may be.

In light, heat, and electricity, or magnetism, nature has exhibited principles which do not occasion any appreciable change in the weight of bodies, although their presence is manifested by the most remarkable mechanical and chemical action. These agencies are so connected, that there is reason to believe they will ultimately be referred to some one power of a higher order, in conformity with the general economy of the system of the world, where the most varied and complicated effects are produced by a small number of universal laws. These principles penetrate in all directions; their velocity is prodigious, and their intensity varies inversely as the

square of the distance. The developement of electric currents, as well by magnetic as electric induction, the similarity in their mode of action in a great variety of circumstances, but above all, the production of the spark from a magnet, the ignition of metallic wires, and chemical decomposition, show that magnetism can no longer be regarded as a separate, independent principle. That light is visible heat seems highly probable; and although the evolution of light and heat during the passage of the electric fluid may be from the compression of the air, yet the developement of electricity by heat, the influence of heat on magnetic bodies, and that of light on the vibrations of the compass, show an occult connexion between all these agents, which probably will one day be revealed; and in the mean time it opens a noble field of experimental research to philosophers of the present, perhaps of future ages.

EXPLANATION OF TERMS.

Electro-Magnetism — The science which determines the reciprocal action of electricity and magnetism.

Electro-Dynamics — The science of the motion and reciprocal motion of electric currents.

Galvanism — Electricity perpetually in motion, and produced by chemical action.

Galvanic Battery — An instrument for producing galvanic electricity, constructed of alternate layers of two metals and a fluid.

Helix — A curve like a corkscrew, whose turnings may either be circular or elliptical.

Magnetic Induction — The effect of magnets to excite magnetism in bodies near them.

Poles of a Magnet — Points in a magnet where the intensity of the magnetic force is a maximum; one of these attracts and another repels the same pole of another magnet.

Rotation — The motion of a body round an axis.

Tangent — A straight line touching a curve in one point.

[From the Knickerbocker, June 1837.]

ELECTRO-MAGNETISM.

It was the illustrious Kepler, if we recollect rightly, who, half piqued at finding that one of his attempts to explain the motions of some planet had been labour lost, compared Dame Nature to the coquette Galatea, in one of Virgil's Eclogues. The nearer she is approached, the more wayward, capricious, and provoking, are her escapadas:

'Fugit ad salices et se cupit ante videri.'

If this be true of astronomical science, it is a truth a thousand times more frequently enforced upon the votary of that class of physical sciences, of which electricity and galvanism form so prominent and interesting a field, both for study and discovery. The very subject-matter of his researches is more like the idea of a 'spiritual essence' than actual *bonâ fidê* material entity. It is a kind of invisible *tertium quid*, which baffles all human tests of materiality. Grant, as some philosophers will have it, that it is merely 'a *property* of matter,' and that it has none of the ordinary characteristics of material substances — yet the difficulty is but increased. If we find it so impossible to believe that matter could travel through matter, with the mysterious velocity with which electricity is impelled; if we cannot conceive of matter which is so subtile as to elude all our senses to penetrate the most solid substances, and to be known only by its effects when in motion, how can we conceive of a mere 'property of matter' of which matter may be deprived in one part, while it is accumulated in another? Of which, in fact, matter, organic or inorganic, is equally unconscious, until a change in its distribution is effected, that developes its latent energy? To call it a mere property of matter, then, like extension, does not seem either very correct in expression, or philosophical in principle.

And, on the other hand, to consider it as matter, as a distinct material substance, is so violent a blow at our almost innate ideas of all matter, that one is half tempted to reject the arguments of the philosophers, numerous as they are, which appear to establish its substantiality beyond a question, and to resort to the convenient nomenclature of the old school men, who would probably have christened it 'the *soul* of matter'—'*anima mundi*'—or some such fanciful name. In fact, so much more subtile than light itself is this mysterious *ens*—so much more diffusive than the invisible winds of heaven—so much more obscure in its nature, and wonderful in its effects, than any other known chemical agent—that we are in favour of every gentleman and lady's forming their own hypothesis, with respect to its materiality or immateriality. And vile as the pun may seem—and in fact is—it is no *matter* whatever, in a scientific point of view, whether it be matter or not. Like the two rival theories of the nature of light, either serves to classify the phenomena; and sometimes they are best explained on one and sometimes the other supposition. Perhaps the idea that it is neither the one nor the other, but the grand connecting link between the material and the immaterial world, would be as convenient a hypothesis as either. Indeed, we beg leave to suggest to some 'ingenious young gentleman,' whether it would not be worth his while to maintain that theory, upon a fitting occasion, before a suitable audience, with a view to impress upon them with due force, that there are more things in heaven and earth than are dreamt of in the philosophy of undevout astronomers and our other modern Sadducees. Although philosophers of all ages and nations have, for the most part, held that electricity was strictly material, we are at a loss to find any stronger arguments in favour of that doctrine, than are to be found in favour of the materiality of light. And Sir John Herschel and Sir David Brewster, 'who ought to know,' both hold that light has no such distinct material existence, but that it is the result of certain vibrations or undulations of a subtile etherial medium, universally present in nature,

just as pulsations of air produce the sensation of sound upon the accoustic nerve. But startling as this may appear, we do nevertheless *en revanche* propound it, to those and all other disciples of the undulatory theory, who maintain the immateriality of light upon this foundation. — How and where has it been proved, that sound itself may not be a *material emanation*, from the mere impact of particles of matter, as much as galvanism or electricity from their more energetic excitement? One would have thought, that the prismatic decomposition of light alone was sufficient to establish the Newtonian theory of light, as a material emanation from luminous bodies. For how a vibration or undulation of an ethereal medium could be thus decomposed into distinct rays, possessing different and in some respects totally opposite properties, it is not very easy to conceive. Though we admit that is is difficult for us to comprehend how matter can be divided into such inconceivably subtile particles, as the Newtonian theory of light supposes, yet we find it a much harder task to acknowledge that a mere undulation of a homogeneous, ethereal medium can produce such surprising chemical results as solar light is well known to be capable of affording.

Now, the nature of light is still enveloped in such profound obscurity — its subtile particles, if it be really material, do so elude all our feeble efforts to condense them — that it would be but an idle indulgence of the fancy to predict what the progress of scientific investigation may yet effect in that department of philosophy. Yet we will, for once, venture the prophecy, that if any great advance is made, by inductive research, toward a more perfect knowledge of the nature and material constitution of light, it will be by a diligent and accurate examination of its magnetic properties. The question is not yet solved, whether light really possesses magnetising powers or not. Morichini, who first asserted it from actual experiment, was more fortunate in his process than subsequent observers, or he was mistaken in his results. If it should be hereafter satisfactorily established, that solar light possesses this property, it may lead to the most important induc-

tions in electricity, galvanism, and magnetism. The whole science of chemistry may undergo a shock as revolutionary as that which it received when the gases were discovered. It might conduct us to the conclusion, that electricity, galvanism, and magnetism, are not only identical with each other, as is now generally admitted, but also with latent heat; and that, though subject to great and essential modifications, they all have their common origin in that decomposition of light which is effected by absorption. There are so many observed phenomena which point to the diurnal changes in the solar light as the cause of the diurnal variations of the magnetic needle, that we have long since considered that as a solved problem. If, therefore, future experiments should fail in proving the absolute mrgnetising power of the solar rays, it would not necessarily follow that the decomposed rays of light — that is, decomposed by *absorption*, and converted into electrical currents — did not possess that power in a very high degree. For that electrical or magnetic currents are produced by the action of the sun's rays upon the earth, has been so well proved, that it must now be taken as a postulate in the science.

No truth should be more frequently enforced upon the devotee of physical science, than this: that the grand chemistry of nature is performed with a sublime harmony and tranquillity, which scarcely make the results perceptible to our senses, save from the lapse of time. There are no violent agents, and rëagents in her labratories; no torture of analysis; no compound blow-pipes, or galvanic batteries; no open war of acids and alkalies, to carry on her mysterious and eternal series of production and re-production. All is inspired with the vital principle of vegetable production; and animal life seems to be but a natural consequence. The germs of vegetation must be cöeval with the particles of matter: the vivifying rays of light can alone bring them into action, and mature them. What wonder, then, if we shall find hereafter, that the same noiseless but irresistible operation of solar light is the basis of all electrical excitement? How are we to ac-

count for the energetic action of the dry galvanic columns of De Luc and Zamboni, except from the excitement of a latent absorbed fluid, brought into action only by the attraction of opposite *absorptions!* The chemical action of the materials of the dry column is quite out of the question, whatever it may be in the galvanic battery of metallic plates and diluted acid. Upon the whole, therefore, it seems reasonable to suspect, that light is alike the source of all vegetable life, and electrical excitement, through the whole solar system.

That the universal presence of this mysterious power was the basis of Newton's almost divine philosophical system — that he considered its existence demonstrated — is apparent, from more than one passage in his '*Principia.*' He appears to have entertained the belief, that future observations would make us more fully acquainted with its nature and properties; but for a century after, little or no progress was made in the vigorous investigation of the phenomena which he had suggested, and yet the elements of the science were familiar to thousands of philosophers. The electricity of amber — the Greek name of which (ἤλεκτρου) still gives the science its appellation — was known to the Greeks, and probably, from the earliest times. But it was not until the identity of lightning and electricity was established, that the science began to assume its proper rank and attraction. Incessant experiments have now raised it to such importance, that, considered as embracing galvanism, electro-magnetism, and last, not least, *electro-dynamics*, it has become the task of the best talent and the longest life to master it, in all its details.

The department of *electro-dynamics* — which is merely conversant with the force of electricity in motion — is daily and hourly extending its limits, and developing powers which are as astonishing in their mechanical effects, as they are mysterious and wonderful in their origin. The most successful cultivator of this branch of it, and one to whom science in general is deeply indebted, is Ampère, one of that illustrious band of French savants, who deserve to have statues erected to them in the temples of science, throughout the civilized

world. Biöt and Arago, names reverenced wherever the light of science has penetrated, also engaged with ardour in the research. In England, Davy and Faraday, soon after, with equal zeal, entered upon the same career. The latter still lives to pursue the enlightened course of investigation by which he has already achieved so many honourable distinctions. Long may he live to reap the same enviable rewards of fame, which have thus far crowned his labours.

But splendid as have been the contributions of these illustrious individuals, to the mere science of electro-dynamics, in illustrating its principles, we think we may venture to claim for our ingenious countryman, Mr. DAVENPORT, the palm for a successful combination of mechanical ingenuity with the scientific principles of electro-magnetic action. It would seem as if he had been guided in his researches by a sort of Yankee intuition, which enables a certain portion of that inventive race to run through a whole science by a series of shrewd 'guesses.' The history of his labours is too characteristic to be omitted. He first saw a galvanic magnet, it appears, about three years ago! — and from the wonderful effects produced by suspending a weight of one hundred and fifty pounds from a small galvanic magnet, he immediately inferred, without any knowledge of the theory or the experiments of others, that he could propel machinery by galvanic magnetism! He purchased the magnet, and produced his first rotary motion in July, 1834, only six months after. In point of date, this appears to be the first successful application of galvanism to the generation of motion, that promised to be of practicable application, upon a large and perhaps even an indefinite scale of power — limited only by the usual boundaries of size and expense. To attempt a description of it, professing to elucidate its construction, would, we fear, be more apt to mislead than to convey any clear idea of its parts, or its peculiar operation. Suffice it to say, that, by arranging a certain number of fixed electro-magnets in a permanent circle, and an equal number in a revolving wheel, the application of the electric current of a galvanic battery produces, — by means of a most

surprising mechanical contrivance, in instantly reversing the poles, as the moveable magnetic circle revolves, — a rotary motion, of the most astonishing velocity and power, considering the feeble agents employed.

The public, we hope and trust, will not rest satisfied, until they have an opportunity at once to gratify a laudable curiosity, and to contribute their mite to the cause of science, at a public and we hope not unproductive exhibition. The ingenuity of the inventors would easily put into motion a variety of useful machinery, which would exemplify the advantages and the wonderful effects of the invisible power which they have enchained and imprisoned as a mechanical drudge to do fealty and service to the human race. A more novel and instructive spectacle could hardly be conceived, than such a practical application of it might be made to exhibit. We are glad to hear that individuals, whose enlightened views and intelligence are sustained by wealth and public spirit, have taken shares in this interesting enterprise, with a liberality and munificence which entitle them to rank among the benefactors to science. In the view of these manifestations of scientific ardour, of enlightened zeal, and mechanical ingenuity, we hope for the most favourable results for their efforts, if success may be commanded in this age and generation.

Electro-Magnetism.
Davenport's Invention.

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OVERDUE