AN

ESSAY

ON THE

HISTORY, PRACTICE,

AND

THEORY,

OF

ELECTRICITY.

BY JOHN BYWATER.

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PREFACE.

The Author has endeavoured, in this small Essay, to collect and combine, in a manner as comprehensive as possible, whatever is material to be known of the present state of Electricity; with the view, as well of informing those who are but little acquainted with the science, as of retracing to the mind of the more advanced and theoretic electrician, an idea of the most important facts and experiments known at the present period.

In the Historical Part, the authority of Dr. Priestley has been relied upon, and his observations, in some instances, adopted.

In the Practical Part, those experiments which were thought the most striking and important have been inserted, and some interesting new ones introduced; but the usual explanations, being considered unsatisfactory, have not in many instances been applied ; nor did the Author think it right to attempt their illustration, by the principles advanced in the Theoretic Part of this work, because they are not sufficiently established by experience.

If the mind examine the subject attentively, uninfluenced by any particular bias to the opinions of eminent electricians, it must be evident, that the ingenious theories, which obtain at the present day, are far from affording a clear elucidation of the various appearances and effects of electricity.

The inquiries of the Author have been essentially aided by the light which a number of recent discoveries have, either by analogy or by direct evidence, thrown upon the science; reasoning from the particular bearing of these discoveries on the subject, as well as from the facts and information previously known, has led him to those peculiar opinions which will be found in the last division of the Essay.

In submitting his particular view of the subject to electricians, the Author wishes to direct their observation to the theoretic state of the science about the year 1747 ; they cannot fail to remark the striking consistency of the opinions now published, with some of those contained in the writings of electricians about that period.

In earnestly soliciting the attention of the scientific to this interesting subject, the object most desired by the Author is to stimulate a spirit of inquiry, from which may result a theory founded on principles more analogous to those general laws which are known to regulate the operations of the material world.

This being the leading motive for the publication of the following Treatise, the Writer believes he cannot in any instance have been betrayed into the slightest illiberality, towards those from whom he has differed in opinion.

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HISTORICAL

ELECTRICITY.

PART. I.

FEW mental employments give more pleasure to the philosophic mind than tracing the history of the sciences, and marking out those peculiar and important events which have led to their present state of improvement.

By following the steps which led to many discoveries in electricity, we shall perceive the power and sagacity of genius, and that display of human intellect which cannot fail to raise our admiration: while, on the other hand, we shall find numerous and important discoveries have resulted from the unwearied researches of men who were not distinguished for their genius; and this consideration holds out the fairest prospect that the labours of the experimentalist will not go unrewarded.

When regarding the progressive advancement of knowledge, and the regular extension of the powers of the human mind, produced by the acquisitions of science, it is painful to observe how, in dark and superstitious ages, obstacles were thrown in the way of the studious, and attempts were made to excite a prejudice against the votaries of natural philosophy, by the most disgraceful perversion of their peaceful labours, to gratify an intolerant spirit of bigotry. Happily the rise and progress of electricity have not been clouded or perverted by the ignorance of early times, as its most important events have chiefly resulted from the inquiries of electricians who lived in the last century: the history of this science is therefore clear and instructive, and powerfully stimulates the mind to further investigation.

We are informed that the attractive power of amber was known several hundred years before the Christian era; yet it does not appear that the subject commanded the attention of the learned until the year 1600, when Dr. Gilbert, of Colchester, published a list of different substances that acquire this attractive property by a slight degree of friction. "This electrical attraction Dr. Gilbert supposed was performed in the same manner as the attraction of cohesion: two drops of water, he observed, rushed together when they are brought into contact; and electrics, he says, are virtually brought into contact with the bodies they act upon, by means of their effluvia, excited by friction." Mr. Boyle, who flourished about the year 1670, afterwards added to the list of substances that Gilbert had published, and made some remarks on the electric light of diamonds.

After Gilbert and Boyle; Mr. Hawksbee, who wrote in 1709, distinguished himself by several new discoveries in electricity. This gentleman was the first who observed the great electric power of rubbed glass, the light and noise proceeding from it, together with a variety of phenomena relating to electrical attraction and repulsion. Some of the experiments made by Mr. Hawksbee, were so singular that they still deserve to be noticed. This gentleman "lined more than one half of the inside of a glass globe with sealing-wax, and, having exhausted the globe, he put it into motion; when applying his hand to excite it, he saw the shape and figure of all the parts of his hand, distinctly and perfectly, on the concave superficies of the wax within: it was as if there had only been pure glass, and no wax interposed between his eye and his hand. The lining of wax, where it was spread the thinnest, would but just allow the light of a candle to pass through it; and in some places the wax was at least one eighth of an inch thick, yet even in those places the light and figure of his hand were as distinguishable as in any other part." Mr. Hawksbee was not inattentive to the sound made by the emission of the electric matter, and observed that all the electric phenomena were improved by warmth, and diminished by moisture, which he proved by several experiments.

We next come to the labours of an experimentalist, perhaps more assiduous in this new field of inquiry than any of his predecessors. Mr. Stephen Grey, a pensioner at the Charter House, was the first that conveyed the electric fluid along certain bodies to any considerable distance. This he put into practice in the beginning of the year 1729, by exciting or rubbing a glass tube, while he stood in his balcony, and then bringing the excited part of the tube in contact with the upper part of an hempen string, which descended to the court below, for he found that a small ivory ball, which was attached to the lower end of the string, would attract and repel light bodies, when he had electrified the string with his excited glass tube. Mr. Grey next made an attempt to convey the electric fluid in an horizontal direction, and from his endeavours to accomplish this object arose a discovery of which he had not the least conception. To complete the object he had in view, he made a loop at each end of a packthread, and hung one end upon a nail driven into a beam; then, through the loop at the lower end of the packthread, he passed one end of the hempen line, along which the fluid was to be conveyed, and fastened the other end of the hempen line to his glass tube: by this means the greater part of the hempen line was suspended between his tube and the lower loop of the packthread, and lay in an horizontal direction, while another part of the line hung in a perpendicular direction from the packthread loop; and to the lower end of this part of the line was attached an ivory ball. After this preparation, Mr. G. expected that when small bodies were placed near the ivory ball, they would be attracted by the ball at the time the other end of the line was electrified by the tube; but to his very great surprise he could not convey the least electric fire to the ball. Soon after this he paid a visit to Mr. Wheeler, and told him of his fruitless attempt to convey the electric fluid along an hempen line suspended in an horizontal direction. Mr. Wheeler then proposed to suspend the line to be electrified by another of silk, instead of pack-thread; Mr. Grey observed that it might do better on account of its smallness, as the electric fluid most probably would not pass so readily to the beam by this silk line as by the packthread. These gentlemen then suspended the line to be electrified by silk, and found the experiment succeed far beyond their expectation.

We are now on the eve of a discovery that may justly be numbered among the most important discoveries in electricity: the following circumstances will however shew, that the discoverers owed more to their unremitting assiduity than to any great depth of reasoning. Elated with the success of their last experiment, these gentlemen afterwards tried to convey the electric fluid along a much longer hempen line, still supposing that their success depended on the smallness of the line that suspended the one along which the fluid was to be conveyed; this persuasion gave them considerable trouble, though in the end it led them to the important discovery to which I allude. After the communicating line had been much extended, its encreased weight, and the motion given it by rubbing the tube, broke the silk line by which it was suspended. This led them to imagine, that metal wire would answer their purpose better than silk, because wire of the same diameter as the silk line, would be much stronger: accordingly they suspended the communicating line by a brass wire, and electrified it with the glass tube, but, to their great astonishment they could not convey the least electric fluid to the ivory ball at the other end of the line; therefore, they were almost compelled to come to this conclusion, that the success of the experiment did not depend on the size of the lines, but on the nature of the materials of which those lines were constructed. This discovery gave birth to numberless new experiments: it was soon found that many other substances, besides silk, would not convey the electric fluid from one place to another: glass, resin, jet, copal, sealing wax, air, most dried animal substances, and all the precious stones, were of this kind; therefore all those bodies which would not convey the electric fluid were called electrics, or non-conductors of electricity: and all those bodies, such as stony and metallic substances, that would convey the electric fluid, were called conductors or non-electrics, and this distinction is retained to the present period.

After this time we find many inanimate, and also animate bodies, were suspended by silk lines, or placed on glass, resin, &c. to be filled with the electric fire. Mr. Grey suspended a pole, twenty-seven feet long, by hair lines, in an horizontal direction, and was enabled to convey the electric fluid from one end to the other. This gentleman then suspended a boy on hair lines, in a similar position, and found that the boy as well as the pole, was capable of being filled with electricity. "Mr. Grey having discovered that he could communicate electricity to a bottle of soap and water, was encouraged to attempt communicating it to the latter. In order to this, he electrified a wooden dish full of water, placed on a cake of rosin, or a pane of glass, and observed that if a small piece of thread, a narrow slip of thin paper, or a piece of sheet glass, was held over the water in an horizontal position, at the distance of an inch, or something more, they would be attracted to the surface of the water and then repelled; but he imagined that these attractions and repulsions were not repeated so often as they would have been if the body had been solid."

Mr. Du Fay, by pursuing Mr. Grey's experiments to make water receive electricity, found "that all bodies, without exception, whether solid or fluid, were capable of receiving it, when they were placed on glass or sealing-wax slightly warmed, or only dried, and the excited tube was brought near them; he particularly mentions his having made the experiment with ice, lighted wood, red hot iron, coal, and every thing that happened to be at hand at the time, and, to his great surprize, remarked that such bodies as were of themselves the least electric, had the greatest degree of electricity communicated to them, by the approach of the excited tube." Mr. Du Fay was the first that observed an electric spark from a living body; this gentleman having suspended himself on silk lines, "as Mr. Grey had done the boy mentioned above, observed, that as soon as he was electrified, if another person approached him, and brought his hand within an inch, or thereabouts, of his face, legs, hands, or cloaths, there immediately issued from his body one or more pricking shoots, attended with a crackling noise; he says this experiment occasioned to the person who brought his hand near him, as well as to himself, a little pain resembling that of a sudden prick of a pin, or the burning from a spark of fire; and that it was felt as sensibly through his cloaths, as on his bare face or hands. He also observes, that, in the dark, those snappings were so many sparks of fire."

Mr. Grey and his friends suspended an iron-rod, four feet long, and half an inch in diameter, upon silk lines, and by applying the excited tube to one end of it, they perceived not only a light upon that end of the rod to which they applied the tube, but a stream of electric fire issuing from the other end at the same time; they then connected a pewter plate with the iron rod, and found the plate produced similar effects to the iron rod when electrified. They afterwards filled the plate with water, and Mr. Grey observes, "they found the same light and the same pricking at the finger, and the same snapping, as when the experiment was made on the empty plate." These experiments appeared so singular, that they induced a general spirit for electrical inquiry, in several parts of Europe, and in which Germany took a considerable share.

About 1742, Mr. Boze, a German philosopher, substituted a glass globe instead of the glass tube, and, by rubbing it with the hand while it turned on its axis, he was enabled to excite a much greater quantity of electric fire than could be obtained by the glass tube. This gentleman was the first who suspended an iron or tin tube on silk lines, to receive the electric fire from the excited globe; and to prevent the tube from injuring the glass, he hung a bundle of threads from one end of the tube, which reached to the surface of the globe, in order to collect the electric matter.

Mr. Winckler, of Leipsic, substituted a cushion instead of the hand; and Mr. Gordon then adopted a cylinder instead of a globe, which is generally adopted at the present period. The accumulation of electricity, acquired by these means, gave a more important air to electrical experiments, and imparted fresh energy to the lovers of this delightful study.

In England, Dr. Watson took the lead, and furnished the public with many entertaining experiments. This gentleman fired spirits of wine, inflammable air, and gunpowder, by the electric spark. He afterwards imitated the Germans, and excited four glass globes at the same time; and found, when "two pewter plates were held, one in the hand of an electrified person, and the other in the hand of one who stood upon the floor, the flashes of pure and bright flame were so large, and succeeded each other so fast, that, when the room was darkened, he could distinctly see the faces of thirteen persons, who stood round the room."

In the preceding observations, it has been my intention to arrange the most important discoveries in such a manner, as to enable those who know but little of electricity, to follow, step by step, the advances of this science, and, in some measure, to anticipate the experiment that led to a discovery whose effects are the most singular in the history of natural philosophy. We have seen that the discoveries of Messrs. Grey and Wheeler enabled electricians to charge all conducting bodies with electricity, when those bodies were suspended by silk lines, or placed on any non-conducting body; therefore, we shall perceive, that this circumstance naturally suggested the experiment that led to the discovery to which I allude.

Professor Muschenbroeck observed, that when conducting bodies were placed on glass, &c. and electrified, that their electricity was very soon carried off by the conducting particles floating in the atmosphere; he therefore imagined, that if a conducting substance was put into a glass phial, that it could be charged much higher than in open air, as the glass would protect it from the dissipating action of the atmosphere. About 1745, he tried to put this idea in practice, by filling a small phial with water, which is a conducting substance. In making this experiment, the professor passed the end of a wire through the cork of the phial, so as to touch the water, and then charged the water by bringing the wire in contact with the prime conductor, but found no extraordinary result from the experiment. Mr. Cuneus, of Leyden, who was one of the party when the professor made the experiment, repeated it afterwards; and happening to hold the phial in his hand, after he had connected the wire with the prime conductor, until the water, as he supposed, had received a full charge of electricity, and then applying his other hand to unloose the wire from the conductor, he received such a sudden shock in his arms and breast, as filled him with astonishment.

Thus we see how gradually these philosophers were led to the discovery of what is called the Leyden experiment, an event on which the eyes of Europe were immediately turned with eager attention. Dr. Priestley remarks, "It was this experiment that gave eclat to electricity, from this time it became the subject of general conversation, and every one was eager to see and feel the experiment, though such terrible accounts had been given of its effects. The most remarkable account is that of Mr. Winckler of Leipsic; he says, that the first time he tried the Leyden experiment, he found great convulsions by it in his body; and that it put his blood into great agitation; so that he was afraid of an ardent fever, and was obliged to use refrigerating medicines; he also felt a heaviness in his head, as if a stone lay upon it. Twice, he says, it gave him a bleeding at the nose, to which he was not inclined. His wife (whose curiosity it seems was stronger than her fears) received the shock only twice, and found herself so weak, that she could hardly walk; and a week after, upon recovering courage to receive another shock, she bled at the nose after taking it only once."

Professor Muschenbroeck tried the experiment with a thin glass bowl, and said, that he would not take a second for the kingdom of France. "But we are not to infer" (Dr. Priestley remarks) "from these instances, that all electricians were struck with this panic. Few, I believe, would have joined with the cowardly professor, who said, that he would not take a second for the kingdom of France. Far different from these were the sentiments of the magnanimous Mr. Boze, who, with a truly philosophical heroism, worthy of the renowned Empedocles, said, he wished he might die by the electric shock, and furnish an article for the Memoirs of the French Academy of Sciences. But it is not given to every electrician to die in so glorious a manner as the justly envied Richman."*

The Leyden experiments, made about 1746, were chiefly made with phials filled with water. But in 1747, Dr. Bevis covered a pane of glass on both sides with tin-foil, excepting about an inch from the edge, all round the pane, and found that it gave very powerful shocks. Afterwards Dr. Watson coated large jars, both inside and out, with leaf silver, and the power of the Leyden experiment became encreased by these means to such a degree, as to melt wires, and kill birds

* This gentleman was killed at Petersburgh by a flash of lightning, which he had incautiously invited into his room while making some experiments on atmospheric electricity.

and fishes. In the next advances of this science we shall have to consider the effects of the Leyden experiment on a more extended scale of action. The French philosophers were the first to appear in this new field of inquiry: they made a shock pass through wire two thousand toises, or about two English miles and a half in length, though part of the wire dragged upon wet grass, went over hedges, palisadoes, and grounds newly plowed up; they also found that when a wire of one thousand three hundred and nineteen feet, with its extremities brought near each other, was electrified, the electricity ceased at one end the moment it was taken off at the other.

The discoveries of the French occasioned this branch of electricity to be carried still further by the English philosophers: Dr. Watson, with the assistance of several gentlemen, made a great number of experiments, on what is called the electric circuit; the most extensive of which was made upon "Shooter's Hill, on the 14th of August, 1747, at a time when there had been but one shower of rain during the five preceding weeks. In this experiment, the wire, communicating with the iron rod which made the discharge, was six thousand seven hundred and thirty-two feet in length, and was supported all the way upon baked sticks, as was also the wire which communicated with the coating of the phial, which was three thousand eight hundred and sixty-eight feet long, and the observers were distant from each other two miles. The result of the explosion demonstrated, to the satisfaction of the gentlemen present, that the circuit performed by the electric matter was four miles: viz. two miles of wire, and two of dry ground, the space between the extremities of the wire, a distance which, without trial, as they justly observed, was too great to be credited. A gun was discharged at the instant of the explosion, and the observers had stop-watches in their hands to note the moment when they felt the shock ; but, as far as they could distinguish, the time in which the electric matter performed that vast circuit might have been instantaneous."

Although the effects of electricity are viewed by the greater part of mankind as mere matter of curiosity, yet the man of science takes a nobler and more extended view of the subject ; he is anxious to pry into the hidden laws of nature, and discover, if possible, what part this active agent is performing in the busy scene of creation ; and in no instance has this laudable spirit of inquiry been more gratified than by the discovery to which I shall now solicit the attention of the reader.

That there is strong similarity between the effects of lightning and electricity was very early remarked by several electricians; but the method that proved, by experiment, that lightning and electricity were exactly the same agents, was proposed by the justly-celebrated Franklin. This philosopher first suggested the idea of drawing electricity from the clouds, by pointed conducting bodies; for he had often observed the great power pointed bodies had in collecting artificial electricity. The doctor, after having published his hypothesis concerning the sameness of electricity with the matter of lightning, "was waiting for the erection of a spire, in Philadelphia, to carry his views into execution, not imagining that a pointed rod, of a moderate height, would answer the purpose, when it occurred to him, that, by means of a common kite, he could have a readier and better access to the regions of thunder than by any spire whatever." The kite that Dr. Franklin intended for this purpose was prepared in the following manner: to the top of the kite a pointed wire was fixed, to collect the electricity from the clouds, which the doctor supposed would descend the hempen string by which the kite was to be suspended. To the lower end of the hempen string a small key was to be attached, and to this key a few feet of silk line, by which the kite was to be held when elevated; and as silk is a non-conductor of electricity, he conceived it would prevent the fluid that descended the hempen string from escaping to the earth. Dr. Franklin, having his kite thus prepared, took an opportunity, the first approaching thunder-storm, to put his plan into practice; but dreading the ridicule which too commonly attends unsuccessful attempts in scientific inquiries, he communicated his intended experiment to no one but his son, who assisted him in raising the kite.

"The kite being raised, a considerable time elapsed before there was any appearance of its being electrified. One very promising cloud passed over it without any effect; when, at length, just as he was beginning to despair of his contrivance, he observed some loose threads of the hempen string to stand erect, and avoid one another, just as if they had been suspended on a common conductor. Struck with this promising appearance, he immediately presented his knuckle to the key, and (let the reader judge of the exquisite pleasure he must have felt at that moment) the discovery was complete. He perceived a very evident electric spark; others succeeded, even before the string was wet, so as to put the matter past all dispute; and when the rain had wetted the string, he collected fire very copiously." By this means the doctor was enabled to charge phials at the key, and collect sufficient electric fire to perform many of those experiments which are usually exhibited by the electrical machine.

These results the doctor obtained in June, 1752, a month after the electricians in France had obtained the same, but before he had heard any thing of their experiments. "Besides this kite, Dr. Franklin had afterwards an insulated iron rod to draw the lightning into his house, in order to make experiments whenever there should be a considerable quantity of it in the atmosphere, and that he might not lose any opportunity of that nature, he connected two bells with this apparatus, which gave him notice, by their ringing, whenever his rod was electrified."

Mr. De Romas was the first that interwove a wire into the string of an electrical kite, and the kite this gentleman used was seven feet and a half high, and three feet wide: "By the help of this kite, on the 7th of June, 1753, about one in the afternoon, when it was raised 550 feet from the ground, and had taken 780 feet of string, making an angle of near 45 degrees with the horizon, he drew sparks from his conductor, three inches long, and a quarter of an inch thick, the snapping of which was heard about 200 paces." "The quantity of electric matter brought by this kite from the clouds, at another time, is really astonishing. On the 16th of August, 1756, the streams of fire issuing from it were observed to be an inch thick, and ten feet long. This amazing flash of lightning, the effect of which on buildings, or animal bodies, would perhaps have been equally destructive with any that are mentioned in history, was safely conducted by the cord of the kite to a non-electric body placed near it, and the report was equal to that of a pistol." But the great practical use of this discovery was to secure buildings from being damaged by lightning: "This great end Dr. Franklin accomplished by so easy a method, and by so cheap, and seemingly trifling apparatus, as fixing a pointed metalline rod higher than any part of the building, and communicating with the ground, or rather the nearest water. This wire the lightning was sure to seize upon, preferable to any other part of the building, whereby this dangerous power would be safely conducted to the earth and dissipated, without doing any harm to the building."

Having given a general account of the rise and progress of the most important discoveries in electricity, I shall now proceed to inquire into that part of this science which more particularly belongs to the practical electrician, and lay down some general rules by which those but little acquainted with the subject may perform the most interesting experiments in this extensive branch of natural philosophy.

PRACTICAL

ELECTRICITY.

PART. II.

In the former part of the Essay, a general and historical view has been taken of this interesting science; but this division of the subject will be found more important, particularly to those who are desirous of becoming practical electricians.

The first question that presents itself in this part of the inquiry is, what are the means by which the electric matter is produced or brought into action? It has been remarked, that when amber, jet, copal, or sealing wax is rubbed with flannel, or when a glass tube is rubbed with silk, electricity is excited; and, from a great number of recent discoveries it appears evident, that whenever a body undergoes any physical change, electricity is generally brought into action. Mr. Bennett's excellent electrometer is an apparatus well adapted for detecting the small portions of electricity which are generally put into motion by these changes: Fig. 1. represents an electrometer of this kind. A A is the cap of the electrometer, b b is a pair of gold leaves which are suspended from the cap, and C C is a cylindrical glass which encloses the gold leaves; in the inside of which, directly opposite to each other, are pasted two small strips of tin-foil, which communicate with the brass foot D D; and when electricity is communicated to the brass cap, the gold leaves will fly towards these strips of tin-foil, in order to discharge the electricity they have received from the cap.

Mr. Bennett made a great number of very curious experiments with this delicate instrument, some of which I shall mention. To shew that the evaporation of a small portion of water will bring electricity into action, it is only necessary to place a metallic vessel, with a little water in it, upon the top of the electrometer, then drop a piece of red-hot cinder into the water, and the gold leaves will immediately open, denoting that they have acquired electricity by the action between the hot coal and water. Water thrown up into the air will produce, by falling on the cap of the electrometer, a similar effect. Powdered chalk, when blown from a pair of bellows on the cap of the electrometer, will so far electrify the cap as to make the gold leaves diverge with electricity. Combustible bodies were burnt in vessels placed on the cap of this electrometer, and electricity was excited by the act of combustion. These experiments, and many others, are very accurately detailed by Mr. Bennett in his essay, entitled " New Experiments on Electricity."

Dr. Priestley informs us, that " Mr. Lullin made a long insulated pole project from the side of the Alps, and, on the 29th of June, 1766, observed, that when small clouds of vapour, raised by the heat of the sun, rose near the foot of the mountain, and ascended along the side of it, if they touched the extremity of the pole only, it was electrified; but if the whole pole, and, consequently, part of the hill on which it stood, was likewise involved, it was not electrified. From this Mr. Lullin concludes, that the electricity of the clouds is produced by their passing through the air while the sun shines upon them: but to which of these two circumstances, namely, the motion through the air, or the action of the sun's rays, this was owing, he could not determine, though he made several experiments for that purpose." From the experiments made by the Rev. Mr. Bennett, it is highly probable that the electricity produced, or brought into action, in this instance, is produced by the action of the vapour against the insulated pole, and not by its merely passing through the air, or the action of the sun's rays.

These various facts may give a general idea of the principle of excitation, and shew that whenever particles of matter are put into motion, electricity is generally produced or brought into action; but they do not point out the means by which any very striking experiments can be performed. I shall therefore proceed to explain the nature and manner of using what is called an electrical machine, an apparatus well calculated to produce a large quantity of electricity.

The machine represented as Fig. 2., and in the following description, is made nearly after the plan of Mr. Nairne, but rather less expensive than the one he constructed.

A A A A is the board on which the supporters and pillars are erected, and by which the machine is made fast with cramps to a table. B B B B are two wooden pillars or supporters, the lower ends of which are morticed into the board A A A A, and in the upper ends of which the axis of the cylinder C C C C turns. D D is the winch by which the cylinder is turned on its axis. E E is a piece of wood, a part of which is slided into a groove under the board A A A A, and made fast by the thumb-screw f. G G is a glass pillar, which is fixed to the wood E E, and supports what is called the negative conductor and rubber H H. I I is another piece of wood, part of which is slided into a similar groove under the board A A A A, and is made fast by the thumb-screw j. K K is a glass pillar fixed into the wood I I, and supports the prime conductor L L; to this conductor a number of metallic points are attached, to collect the electric fluid which flows on the surface of the cylinder, and by that means enables us to perform our experiments at the prime conducting rod M M.

In this machine, the rubber, and what is termed the negative conductor, are placed on a glass pillar, to enable us to perform some experiments that are intimately connected with an illustration of the theoretic part of the subject, which will be more fully explained when we come to that part of electricity; therefore a chain must be suspended, from the rubber that will reach to the table on which the machine is placed, in order to make the machine give out a proper quantity of electric fire. To the upper part of the rubber a piece of black silk is attached, which is spread over the top of the cylinder, and reaches nearly to the points of the prime conductor, which prevents the fluid that is brought into action, by the attrition of the cylinder and rubber, from flying into the atmosphere before it reaches the points of the prime conductor; and, at the same time, by its action on the revolving cylinder, tends to encrease the excitation of the machine.

I shall now mention a few things necessary to be observed, in order to make the machine act in a very powerful manner, particularly in damp weather. In dry weather it will generally excite very well, without much precaution, after the rubber has been supplied with a little amalgam*. No-

* To make the amalgam for this purpose, take a small wooden box chalked in the inside, pour about four ounces of mercury into the box; afterwards melt two ounces of zinck and two ounces of tin in a crucible, and pour them upon the mercury: shake the box, and the whole will become united; this amalgam, when cold, must be very finely powdered, and mixed with a sufficient quantity of hog's lard to give it the consistency of paste: it will then be fit for use.

thing is more favourable to a strong excitation than well heating the room, and the electrical apparatus, a few hours previous to using the machine; this will always insure a tolerable excitation, even in the dampest weather. But as it is often desirable to use the machine, when there is not time to take advantage of this, I shall point out another method that will seldom fail of producing a powerful excitation. The machine must be first placed before a fire, gently turning the cylinder, that every part of its surface may become regularly heated; after the machine has been sufficiently warmed, and fastened to the table, and the rubber has been supplied with a proper quantity of amalgam, take a piece of soft leather, and spread a small quantity of amalgam upon it; to this amalgam add a little tallow, and apply the amalgamated leather to the under side of the cylinder when turning; this will generally provoke a strong excitation, and communicate a large portion of the electric fluid to the prime conductor.

Having given directions how to excite the electrical machine, I proceed to the description of a few entertaining experiments, which may be performed by simply applying the apparatus we use to the prime conductor.

EXPERIMENT 1.---If a feather with long downy fibres is stuck into the small hole, generally made in the top of the prime conductor, the fibres will repel each other when the feather is electrified; and if a pointed wire, or a lighted candle, is brought near to them, they will fly from the point towards the conductor, as if animated, which arises from the point instantly depriving them of their electricity.

EXPERIMENT 2.---Fig 3. represents an electrical head of hair. In making an experiment with this head, it is only necessary to fix the brass stem, on which the head is placed, into the hole of the conductor, and when the head becomes electrified the hairs will rise up and avoid each other; if a pointed wire is presented above them, they will recede from it towards the conductor; but if a brass ball is attached to the end of the wire, they will then be attracted by the brass ball, instead of being repelled, as it does not deprive them of their electricity so rapidly as the pointed wire.

EXPERIMENT 3.---Fig. 4. is an apparatus for dancing pith balls: it consists of a cylindrical glass, about two inches wide and five inches long; a wooden cap is fitted to each end of the cylinder, and the inside of each cap is covered with tin-foil; the lower cap is fixed upon the top of a wooden pedestal, and a brass ball and wire is attached to the upper cap. When this instrument is to be used, the ball projecting from the upper cap must be brought to the rod of the prime conductor, and the pith balls within the glass will be alternately attracted and repelled between the two caps, with great rapidity, when the electrical machine is put in motion. In making this experiment, it is necessary that the glass should be very dry, or the fluid will pass down its sides, instead of passing through the air which the glass includes, and prevent the effect intended.

EXPERIMENT 4.---Fig. 5. *represents an electrical orrery.* A A is a brass pedestal pointed at the upper end; B is a wooden ball which represents the sun, and turns on the point of the brass pedestal; C C is a brass wire fixed into the wooden ball B., and a still smaller wire is fitted up with a cap which turns on the pointed end of the wire C C. At each end of this smaller wire a ball is fixed, the largest of which represents the earth, and the smaller one the moon. From the side of the brass wire C C, a very small metallic point projects at d, and another small point projects from the body of the moon at e. Now, when the lower end of the brass pedestal is put into the hole in the upper side of the prime conductor, and the apparatus electrified, the fluid flows from the metallic point d, and, by the resistance the fluid meets with from the air, it reacts on the point with such force as to make the wire C C recede from the point of action; consequently the sun, earth, and moon, all turn round the center of the brass pedestal on which the ball B is suspended. The fluid also, issuing from the metallic point projecting from the body of the moon, reacts in a similar manner on that point and the body of the moon; and as the wire, to which the earth and moon are attached, is much shorter than the wire C C, the revolutions it makes are more rapid than those made by the wire C C, and serve to point out the diurnal motion of the earth and moon.

EXPERIMENT 5.---Fig. 6. represents an apparatus for exhibiting what may be called an *electrical opera.* A A A A is a wooden cross which forms the stand of the apparatus. B is a glass pedestal on which is fixed a circular board, about three quarters of an inch thick, and eighteen inches in diameter, covered on both sides with tin-foil. C C are two glass pedestals which support the wooden brace D D; in the middle of D D a socket is fixed, through which the brass rod E E slides, which is graduated on one side; to the upper end of this brass rod a brass ball is attached, and to its lower end a circular board is screwed, fifteen inches in diameter, and covered with tin-foil like the former. Through the side of the socket, in the middle of D D, a thumb-screw f passes, and presses against one side of the brass rod, which is made flat for that purpose: the upper board can be suspended, at any point between the lower board and the wooden piece D D, by means of this screw. Now, for the sake of illustration, we will suppose the upper board brought in contact with the lower one, and that the graduation of the brass rod commences at that point where the upper surface of the socket in D D intersects the rod, and that the graduation proceeds downwards; therefore, if we slide up the brass rod till the upper side of the socket intersects the scale on the rod at two inches, and then make the rod fast by turning the screw f, we shall perceive that the two boards must be exactly two inches asunder, and that the distance of the two boards must always correspond to that division of the scale on the brass rod which is intersected by the upper part of the socket in the wooden piece DD; this gives a great facility of proportioning the distance of the two boards to suit the paper figures, or any other small bodies, that may be placed between them for amusement. To the top of the brass ball, on the rod EE, is attached, occasionally, a set of musical bells, which are fixed upon the brass ball by a pin projecting from the under side of the large central bell. On the top of the large bell the glass pillar gg is fixed, and on the top of this pillar two cross wires are placed, from which all the lesser bells are suspended; if the knob of the prime conductor is brought in contact with these cross wires, the electricity they receive will pass to the small bells, and thence to the large bell, by means of the small clappers which hang between them; for when the clappers, which are small brass balls suspended by silk lines, become charged by the small bells, they fly to discharge themselves on the large one, and then return to the small bells for a fresh supply, and by this charging and discharging keep a continual ringing by striking alternately the large bell and the smaller ones. The fluid which is received by the large bell is communicated to the upper board by the brass rod E E, and as that board is insulated by the glass pillars C C, its nearest way to the earth is to pass through the portion of air between the boards; and if small paper figures are placed between the two boards, they become the conducting medium by which it passes to the earth, and, by its influence, exhibit many whimsical attitudes when the machine is put in motion. In this experiment the under side of the lower board must communicate with the earth by a wire or chain, or else the bells and figures will not perform to the best advantage. The reason for placing the lower board on a glass pillar will be obvious, when the apparatus is applied for illustrating the charge of a plate of air.

Having described several effects which depend on the motion given to electrified bodies, we shall consider some of a different kind, depending on a portion of light that is brought into action by the electric fluid, and are therefore termed luminous experiments. These, like the former, are made by simply applying the apparatus to the prime conductor.

EXPERIMENT 7.---Fig. 7. will exhibit *a zig-zag line of electric sparks.* In making this experiment the end A must be held in the hand, and the ball B must be brought near the ball of the prime conductor; and for every spark the ball B receives from the conductor, a small spark will pass between each circular bit of tin-foil, placed on the zig-zag line, and make a beautiful appearance: in this as well as all other experiments of this kind, the glass must be warm and dry, or the effect will not appear brilliant.

EXPERIMENT 8.---Fig. 8. is an apparatus for shewing the *word* " *light* " by small *electric sparks.* This apparatus consists of a piece of plate glass, on which five small strips of tin-foil are pasted; the ends of these strips are joined together by other small bits of tin-foil, except one end of each outer strip; the unconnected end of one outer strip is carried forward to the ball A, and the end of the other outer strip is extended to the handle B; therefore, a communication is formed, through every strip of tin-foil, between the ball A and the handle B: across these strips of tin-foil small cuts or separations are made, which correspond to the outlines of those letters that form the word "light."

When the apparatus is held by the handle B, and the knob A is brought to the prime conductor, the knob A will receive a spark that will pass along every winding of the tin-foil, and exhibit a small spark at every point where the tin-foil is cut, which, in the dark, will shew the word "light" in brilliant sparks. Any other word may be exhibited by an apparatus prepared and used in a similar manner. Thin crown glass is sometimes used for this purpose, and a small frame of wood fixed round the glass to give it security; but as the wooden frame is inclined to carry off the fluid, plate glass, without a frame, is preferable.

EXPERIMENT 9.---Fig. 9. will shew a device of different *coloured electric sparks.* This apparatus consists of a piece of plate glass placed perpendicularly: the device is made with spangles of tin-foil, pasted on one side of the glass, which commence at the ball A, and lead through all the various windings to the foot B, which communicates with the earth. On the opposite side of the glass are painted four different coloured squares, corresponding with the squares of the device, and when the coloured side of the glass is turned to the spectators, each square on the device gives sparks of a corresponding colour, the light from each spark having to pass through the painted glass to reach the spectator's eye. As this experiment must be made in the dark, a very pleasing effect may be produced by alternately turning each side of the glass to the spectators, as one side will shew the sparks coloured, and the other give the sparks their common appearance.

Experiment 10.---Fig. 10. represents an apparatus in which four glass pillars are *alternately* illuminated with a *spiral line* of electric sparks. These pillars are fixed into a round board, and in the center of the board another glass pillar is fixed, at the top of which a brass wire, with a knob at each end, is suspended. This wire is made to turn freely on a point, at the top of the glass pillar, and its knobs just to pass within the balls on the top of the other pillars; therefore when the ball of the prime conductor is brought over the center of this wire, and the wire put in motion, while the machine is working, the wire and balls will continue to revolve, and communicate sparks alternately to each pillar as they pass, and thus produce a brilliant and changing effect.

Experiment 11.---Fig. 11. is to represent what is termed an *illuminated dome.* This apparatus consists of five glass pillars placed on a circular board A A, and each pillar shews a spiral line of sparks; in the center of the board another glass pillar is fixed, which supports a glass dome: from the brass ball B, on the top of the dome, the device made with tin-foil spangles commences and passes, in various configurations, round the dome to the pillar C C; but instead of descending that pillar to the board A A, it passes across a small piece of glass that joins the pillar C C with the pillar D D, then passes up the pillar D D, and across the lower part of the dome to the pillar E E, and down that pillar to the piece of glass that unites it with the pillar F F, and up the pillar F F across the lower part of the dome to the pillar G G, then descends that pillar to the earth, which pillar must be uninsulated for the purpose. In using this instrument the ball B, at the top of the dome, must be brought near the knob of the prime conductor, and when the ball B receives a spark from the conductor the whole device will be illuminated.

EXPERIMENT 12.---Fig. 11* is an apparatus to represent the side view of a *bird by electric sparks.* As this device opens a new field for experiments of this kind I shall be rather particular in my description of the manner in which it is made. In the other devices for electrical illuminations the line of sparks pass through various windings, but never intercept each other; in this experiment the spangles will so far interfere with each other, in their different windings, that they will require to be laid on the glass in a different manner from the former. The spangles in the other devices were laid on one side of the glass; but, to represent the complete outline of a bird, it will be necessary that they should be laid on each side of the glass. A A A A represents a square of clear thin crown glass, about nine inches by seven. B is a brass ball attached to the upper edge of the glass. C C is a wooden handle into which the lower part of the glass is fixed. In order to place the tin-foil spangles in a correct manner on the glass, a drawing of the bird is first made on a piece of paper, the size of the glass pane; the paper is then wafered by its corners upon the glass, and a part of the spangles laid on the opposite side, corresponding to the outlines of the drawing: when the spangles are laid on one side of the glass, the drawing must be placed on the other side to complete the bird; the lines of spangles will be readily distinguished from the strips of tin-foil which connect the various parts of the device together, as they are represented by small circles, and the strips of tin-foil are represented by continued lines. To give a clear idea of the quantity of spangles which ought to be laid on each side of the glass, we shall suppose the pane of glass A A A A divided down the middle, then the device, on each side, would be represented by Fig. 12. and 13. which, when joined together, form the device at Fig. 11.* In making this illuminating apparatus, I first wafered the drawing on the glass, and completed that part of the device shewn at Fig. 12; this was done by laying a strip of tin-foil from the ball B to the back of the head; thence commences a line of spangles, which proceed along the outline of the body to the extremity of the lower part of the bill; a strip of tin-foil then passes to the edge of the glass and completes the device of Fig. 12. The drawing must now be removed, and the outlines of the remaining part of the bird, as shewn in Fig. 13., must be pierced with a pin, and then wafered on the contrary side of the glass, and it will be discovered, by the marks of the pin, where to lay on the other spangles to complete the bird, which will be found to correspond to that part of the device shewn at Fig. 13. In Fig. 12. we supposed a strip of tin-foil had been carried from the lower part of the bill to the upper edge of the glass; we will now suppose it carried over the edge, and down the other side of the glass, to the upper part of the bird's bill, thence carried forward by a line of spangles, which completes the remaining part of the bird's head, as shewn at Fig. 13. From these spangles a strip of tin-foil proceeds towards the center of the head, and there forms an angle with another strip, which leads down to the wing: these two strips do not quite join at the angle; consequently, a spark is induced at that point which serves for the eye of the bird: from the lower part of the last-mentioned strip the spangles commence which form the wing, and, from the end of the wing, a strip of tin-foil communicates with those spangles that form the legs and feet, and from the spangles which represent the legs and feet another strip proceeds to the handle C C and completes the device; perhaps the device might be completed with less trouble, if a drawing were made on the glass, in the first instance, and the strips and spangles laid on by the rules described and shewn at Fig. 12 and 13. If the neck and head of the bird are made very small, it will be difficult to prevent the fluid, which is received by the ball B, from passing across the neck of Fig. 12, instead of making the circuit of that device. The tin-foil spangles are readily cut out with a hollow stamp, when the tin-foil is laid on a flat piece of hard wood.

EXPERIMENTS WITH THE LEYDEN JAR.

Hitherto we have considered electricity in its most simple mode of action; but, as we advance, we shall find its effects become more complex and difficult to comprehend, and the performance of the experiments will demand more care and attention.

In the last set of experiments we had nothing more to do than apply the apparatus, on which the electric fluid was to produce the effect proposed, directly to the prime conductor. But in the next we shall have to employ a portion of the electric fluid which is completely detached from the electrical machine, and which has the power to produce some very astonishing effects.

In the first part of this Essay I gave an historical account of what is called the Leyden experiment. I shall now enter more minutely into the nature of preparing a glass jar by which that experiment is generally performed.

Fig. 14. is a glass jar prepared for this experiment in the usual manner: the *outside* and *inside* are covered as high as A A with tin-foil, which is laid on with thin paste or gum-water; B B is a wooden cap, fitted on the top of the jar; C C is a brass wire and knob, the lower end of which passes through the cap B B into the jar, and to its lower end is hung a small chain that touches the inside coating of the jar. These, jointly, viz. a common glass jar, the inside and outside coatings, wooden cap, knob and wire, constitute what is termed a Leyden jar or phial. If we take a jar of this kind in one hand, by its outside coating, and hold the knob to the prime conductor when the machine is working, it will become charged; and if a communication is formed between its outside and inside coatings, by the other hand being brought to the knob, we shall feel that peculiar sensation

called the electric shock. But to shew more clearly that the discharge depends on a communication being formed between the outside and inside coatings of the jar, by a conducting body, we will suppose the jar charged as before, and placed on a table; then if we take the jointed discharging rod by its glass handle A A, Fig. 15, and place the knob B in contact with the outside coating, and while it remains there bring the knob C to the knob of the jar, an explosion will take place between the knob C and the knob of the jar, which will instantly deprive the jar of its electricity. By the charge of a jar that measures about two quarts, prepared in the manner described, several very entertaining experiments can be made.

Experiment 13.---When a jar of this kind is charged in the manner described, and a card placed against the outside coating, then one knob of the discharging rod placed upon the card, and the other knob of the discharging rod brought to the knob of the jar as before, we shall find that the card will be perforated by the discharge of the jar.

Experiment 14.---When the jar is charged as before, take an egg, and hold one end of the egg against the outside coating, and against the other end of the egg place one knob of the discharging rod; and if the other knob of the discharging rod is brought to the knob of the jar, the egg will become illuminated by the discharge. The egg in this experiment may either be held in the hand or laid on the table.

EXPERIMENT 15.---*To illuminate an iron chain.* In this experiment a little more preparation will be necessary than in the other: take six or eight feet of iron chain, and hang it in festoons along a silk line; then connect one end of the chain, by a wire, with the outside coating of the jar: afterwards connect the other end of the chain with the brass part of the discharging rod, and when the jar is charged, and the knob of the discharging rod is brought to the knob of the jar, the chain will be rendered beautifully luminous by the explosion.

EXPERIMENT 16.---Fig. 16. represents what is called the *spotted jar*, which makes a very luminous appearance when discharged; for the space between the points of each square piece of tin-foil will become illuminated when a communication is formed between the outside and inside coatings. I conceive it almost unnecessary to remark, that all the experiments which are intended to exhibit electrical illuminations, will require the room to be as dark as possible, to shew them to the best advantage, and the glass of the apparatus completely free from moisture.

EXPERIMENT 17.---To discharge the jars by the *flame of a candle*, charge two small jars, one with positive the other with negative or resinous electricity. This may be done by taking away the chain from the rubber, and holding the knob of one jar to the rubber, at the same time the knob of the other is held to the prime conductor. Afterwards place them on the table, so that their knobs shall be about three inches from each other; then connect their outside coatings by a chain, and bring the flame of a candle between their knobs, and their discharge will be made through the flame attended with a curious appearance. The exact distance at which the jars should be placed from each other will depend on the strength of the charge; for the stronger the charge, the greater may be their distance. If two or three candles are fixed into a piece of wood, and introduced between the two knobs, an explosion will be made through the whole line of candles, producing considerable variety in their flames.

Experiment 18---will shew that the electricity given out at the *rubber*, has very *different properties* from that given out at the *prime conductor*. In making this experiment, it is requisite to use a mixture of two different powders; the two I have applied in this experiment are red lead and resin. Take about equal quantities of each, and mix them well together: put them into a hair dresser's powder machine; charge a small jar at the prime conductor, and place it on a table; then project the mixt powders upon the knob of the phial, and it will completely separate the resin from the red lead. Discharge the jar, and remove the chain from the rubber to the prime conductor, taking care that it reaches the table. Rub off the resin, and charge the same jar at the rubber; then project another portion of the mixed powder upon its knob, and it will become covered with red lead, contrary to the last experiment. This effect may be obtained under still more singular circumstances, if two small jars are used in the experiment. To produce the effect, let one jar be charged at the prime conductor, and the other at the rubber, as in the preceding experiment; then place them within an inch or two of each other, and hold the puffing machine at about two feet distance, but in such a direction that it shall project a stream of the mixture exactly between the two knobs, we shall find the knob of one jar will become covered with resin, and the other with red lead, agreeably to the last experiment.

Various other methods may be used to project the mixture upon the balls: it may be put into a pair of bellows, and blown upon the electrified bodies, through a piece of muslin, tied over the nose of the bellows: or it may be tied up in a piece of muslin, and shook over the electrified bodies, which will produce a similar effect. Another curious experiment can be made by two phials charged with different electricities. Take a pane of glass about a foot square, perfectly dry; charge the jars as before, one at the prime conductor, and the other at the rubber; lay the pane flat upon the table; take the jar charged at the prime conductor by its coating, and pass its knob quickly round the pane, keeping it about an inch from the edge; then take the jar charged at the rubber, and pass its knob so as to form two cross lines in the center of the pane; and when the mixed powder is projected over the pane, the outer line will select the resin, and the two center lines, which cross each other at right angles, will select the red lead, making a curious configuration on the glass; if the glass is perfectly dry and warm, the configuration will be varied agreeably to any device traced out by the knobs of the jars when passed over the pane: the glass should afterwards be placed in a frame, with a black board behind it; and if the configuration is turned towards the board, it will be protected and shewn to the best advantage.

Experiment 19.---Is to render the end of the finger *completely luminous:* Dr. Priestley discovered, that a powerful charge, passed through an uninterrupted chain, would render the finger luminous, if placed near the interruption. But the apparatus I shall describe, is fitted up purposely for the experiment: in a bit of wood about half an inch thick, an inch and a half broad, and three inches long, make a groove on one side in a longitudinal direction, one eighth of an inch wide, and of the same depth; then pass into each end of the groove a brass wire, leaving a space between their two approaching ends,---about half an inch in the middle of the groove. The outer ends of these wires must extend a little beyond the ends of the wood, and each be furnished with a hook to connect them with a wire or chain, for the purpose of forming a communication between the inside and outside of the jar. The finger then must be placed upon the wood, so as to cover the two approaching ends of the wires ; and when a charge is sent through the line of communication, the finger will be rendered completely luminous.

EXPERIMENTS

MADE WITH THE

ELECTRIC BATTERY.

In the next set of experiments, we shall employ a much stronger electric force, but which acts on the same principle as the charge of a single jar. The apparatus that will furnish us with this extra power is termed an electric battery, and consists, as its name imports, of a number of jars, whose electric powers are united, and explode at the same instant of time. Fig. 17. *represents a battery of nine jars fitted up in the usual manner.* AAAA is a square box, the upper part of which is divided, by narrow strips of wood, into nine cells or partitions, each of which receives a jar; the bottom of the box must be lined with tin-foil, in order to form a communication between the exterior coatings of all the jars: to make it convenient for discharging, a small wire must pass through the side of the box to the tin-foil lining at C, and, at the outer end of this wire, a hook or ring must be made, which will enable us to form a ready communication with the outside of the jars, when we want to discharge the battery. The jars most convenient for a battery of this kind, are about twelve inches deep and four inches wide, not contracted at the top, but have parallel sides from top to bottom; they must be coated inside and out with tin-foil, leaving about four inches from the top uncoated. In fitting up a single jar, in the usual manner, the wire, which forms a communication with the inside coating, passes through a cap fitted on the top of the jar; but in fitting up a battery, it is much better to use a round piece of wood about an inch thick, made to fit the bottom part of the jar in the inside: let this wood be covered on the upper side and edge with tin-foil; then fix a stout brass wire, fourteen inches long, into its center; and when the wood and wire are fixed into each jar, the wires will stand in the middle of the jars, and, by having no communication with the upper part of the jars, an insulation of eight inches will remain between the outside and inside coatings of each jar,---a very desirable thing in a battery, as it tends to prevent a spontaneous explosion, which is often attended with very unpleasant circumstances. After having fitted up each jar with a wire and circular wooden foot, the tops of these wires must be connected together by some conducting substance: to complete this, nine brass balls must be connected together by brass wires, and their distance from each other must correspond to the distance there is between the centers of the jars. In the under side of each ball a hole must be made to receive the upper end of the wires that are fixed into the jars; and when the balls are placed on the wires, the battery is completed, and will have the same appearance as Fig. 17. The experiments made by the battery are very numerous and entertaining.

As the universal discharger will be used in several of these experiments, I shall give a description of that convenient instrument. Fig. 18. is a representation of the discharger. AA is a board that forms the foot or bottom of the discharger: BB is a hollow wooden pillar; into this pillar a small wooden cylinder slides, which is made fast at the height wanted, by the screw b; on the top of this cylinder a round piece of board or ivory is fixed, on which the objects to be electrified are placed: CC are two glass pillars; on the top of these pillars, the wires DD DD turn, by joints, in every direction: these wires can be slided backwards and forwards, as they pass through small sockets fixed on the top part of the joints. When any object is to be exploded or illuminated, suppose an orange, it must be placed on the stand in the center of the apparatus, and the knobs of the directing wires DD DD brought in contact with the opposite sides of the orange; then one directing rod must be connected, by a chain or wire, with the wire C, on the outside of the battery; and the other directing rod must be connected by a wire with the discharging rod; and when the discharge is made by the discharging rod, the fluid will pass through the circuit thus formed between the outside and inside coatings; and, as the orange forms a part of that circuit, it will become luminous by the explosion. Onions, apples, and pears, can be rendered luminous by a discharge from a battery of this force, provided they are wiped dry, and the brass balls are taken off from the directing rods, and the points of the two rods passed a part of the way through the substances which are to be illuminated.

A lump of sugar, chalk, and several other objects, if placed between the directing rods of the universal discharger, will appear luminous, after the discharge.

EXPERIMENT 20.---Fig. 19. represents an apparatus for *illuminating jars* filled with different *coloured water.* The mode generally recommended for rendering jars of water luminous, is by laying a chain on a table, so as one end may touch the outside of a charged jar or battery, and then placing the opposite end of this chain within about a quarter of an inch of another piece of chain, and upon the ends of these two chains place the jar of water to be illuminated; when the jar or battery is charged, form a communication with the last mentioned chain and its inside; and as the line of communication is broken underneath the coloured jar, an explosion will take place where the chains are separated, and the jar will become illuminated. The next apparatus will enable us to illuminate four jars at the same time; and if the jars are filled with different coloured water, they will make a pleasing and varied appearance.

The construction and principle of this apparatus will be seen to advantage at Fig. 20. AAAA is a frame of wood about half an inch thick and two inches deep, which is divided into four divisions, fitted up with wires and balls, as shewn by the drawing, so that two balls shall nearly meet under the center of each jar: these balls must have a space of about one-sixteenth of an inch between them; and when the jars are placed in the frame over them, as in Fig. 19., and a communication formed between the wire C, at the end of the frame, and the hook C, on the outside of the battery, and a conducting connexion formed between the wire D, at the other end of the frame, and the discharging rod, an explosion will be induced between each pair of balls, when the battery is discharged, and by that means the jars become illuminated. To make the circuit through the line of balls more complete, a piece of glass tube is fastened into each wood division, and the wires which hold the balls pass through cork placed in these glass tubes, which prevents the fluid from passing along the frame of the apparatus. In making the experiment with four or more jars, it will be advisable to place those balls rather the farthest asunder, which are intended to illuminate the darkest coloured water; because the farther the balls are asunder, provided they are not too far, the greater will be the explosion, consequently the greater the illumination.

EXPERIMENT 21.---Fig. 21. is an apparatus for rendering a *number of eggs luminous.* AAAA is the frame of the apparatus; and between the two small upright pillars, four small circular boards, with holes in their center to hold the eggs, slide up and down, and can be made fast at any point between the top and bottom of the frame, by the small thumb-screws C C C C, which screw into the circular boards by passing through a slit made in one of the upright pillars; when the apparatus is to be supplied with eggs, the whole of the thumb-screws must be unscrewed, and the circular boards let fall to the bottom of the apparatus. The upper circular board must have an egg placed in its center; then be moved up till the upper end of the egg touches the lower end of the wire DD, and made fast with the thumb-screw C; afterwards the next board and egg must be slided up till its upper end touches the lower end of the first egg, and again made fast; and in like manner all the others must be raised, as shewn by Fig. 21. When this is done, the apparatus will be ready for the experiment. Below the aperture in the lower board, a semicircular piece of brass is fixed, so that the lower end of the bottom egg may rest upon it; to this brass a small hook is attached, by which the lower end of the eggs must be connected with the outside of the battery: a wire must also connect the wire DD to the discharging rod; and when the rod is brought to the knob of the battery, the discharge will render the whole of the eggs luminous.

EXPERIMENT 22.---*To mark coloured rings on different metals;* an experiment first made by Dr. Priestley: Let a plain piece of metal be fixed upon the end of a directing wire, belonging to the universal discharger; and, to the end of the other directing wire, fix a very sharp pointed needle, with its point directed to the surface of the metal. When one directing wire is connected with the outside of the battery, and the other with the discharging rod, and the battery discharged through this circuit, the surface of the metal will be marked with rings consisting of prismatic colours, which are occasioned by the laminæ of the metal raised by the explosion. These coloured rings appear upon any of the metals, and are more or less numerous in proportion to the sharpness of the needle, the point of which is also coloured.

EXPERIMENT 23.---To render *steel magnetic*, and *invert the poles of magnets*, by the discharge of an electrical battery: If a slender piece of steel is tempered in a proper manner, and placed in a longitudinal direction between the directing rods of the universal discharger, and a number of powerful shocks sent through it or along its surface, it will acquire by the action of the electric fluid a sensible polarity: needles, which have been impregnated with the magnetic virtue, will have their virtue destroyed, and, often, their polarity inverted, by being placed in the circuit through which the battery is discharged.

EXPERIMENT 24.---*To perforate paper by an electrical discharge*, take several folds of paper or leaves of a book, about 20, for the discharge of a battery of nine jars, and place them between the knobs of the directing rod, belonging to the universal discharger: when the battery is discharged in the usual manner, the whole of the paper will be perforated; the perforation will take place exactly at that part of the paper which was in a line with the two directing wires of the discharger: if the paper be rather damp, the perforation will be larger than when perfectly free from moisture.

EXPERIMENT 25.---Lay an iron chain upon white paper, and pass the charge of a battery along the chain; and the device, the chain formed, will be shewn by marks left on the paper when the chain is removed, which is caused by a partial deflagration of the metal where the links are united. This experiment shews the advantage of completing the discharging circuit as far as possible with wire instead of chain, as it would leave the charge to act with more force on objects placed in the discharging circuit. Several inches of very small iron wire, when placed in the discharging circuit of a powerful charge, will become red hot, and melt into small globules; sometimes it will be dispersed about the room, and even volatilized by the explosion of the battery.

EXPERIMENT 26.---*To render an iron chain luminous.* To make this experiment with the best effect, it will be necessary to use a very powerful battery; for the stronger the power the more brilliant will be the illumination. In general, the chain to be illuminated is suspended on a silk line, which is made fast in an horizontal direction; this line is passed through several links, in different parts, to make the chain hang below the line in festoons; or it may be hung across the line in any other device; one end of the chain is then connected with the outside of the battery by a wire, and the other end of the chain is connected by a wire to the discharging rod; when a communication is formed between the outside and inside of the battery, by the discharging rod, the chain will become beautifully illuminated by the explosion, throwing out many radiating rays of light at almost every link. This effect depends on a small explosion, which takes place at the point where the links unite: a small portion of the iron is deflagrated at each link, which gives the light a very singular and pleasing appearance; for iron, being a combustible body, gives the light a yellow or gold colour.

Another mode of suspending the chain is to give it the appearance of a star; this is done by placing four nails or pins at four opposite points in the wall, as shewn at A A A A, Fig. 22; these are the points from which the chain is suspended by silk lines; all the lines may be distinguished from the chain, as they are shewn by uninterrupted lines in the figure; the two ends of the chain, which form the lower point of the star, must not unite, but be connected by two lines which unite at the lower point a. One of these ends, as B, must be connected with the outside of the battery, and the other end must be connected with the discharging rod; by which the whole of the chain will be in the circuit between the two sides of the battery; and when a discharge is made, the chain will become brilliantly illuminated, if the charge be sufficiently powerful. Various other devices may be formed on this principle of suspending the chain, and as it is an experiment that seldom fails, it most likely will gratify those electricians who may think it worthy of further consideration.

Experiment 27.---Fig. 23. represents an apparatus *for charging a plate of air*. This is the same apparatus as was used for the electric opera, except that the upper board is taken away, and one substituted eighteen inches in diameter, the same size as the lower one; in using this instrument the boards must be placed an inch or an inch and a half asunder, which is readily done by the graduated brass rod and thumb-screw; after the boards have been placed at a proper distance, and the chain removed from the lower board, it is only necessary to bring the ball A in contact with the prime conductor ; touch the under side of the lower board with one hand while the air between the boards is charging, and then bring the other hand in contact with the upper board, and a shock will be felt the same as from a small Leyden jar. If when the apparatus is charged the two boards are touched alternately, the pith balls, which are suspended by brass wires laid on each board,as bb, will co-lapse and recede from each other, the same as if connected with the coatings of a charged Leyden jar.

In making this experiment, the upper board is generally suspended from the ceiling of the room by a silk line and pully, the inconvenience of which I need not point out, it being so very obvious.

THEORETIC

ELECTRICITY.

PART. III.

Having taken a general view of the historical and practical part of electricity, we shall now enter into one of the most interesting inquiries that can occupy the human mind. It will not be merely to witness the efforts and discoveries of different electricians, but, by an act of rational induction, to discover, if possible, those general laws and properties, which the Deity has assigned to the electric matter. By attentively tracing the history of electricity, it appears evident that electrical opinions obtained a considerable share of simplicity about the year 1747; it was a little previous to this time that Du Fay discovered that glass gave out electricity, which had very different properties from that given out by excited amber, resin, &c.; therefore he very naturally concluded, that there were two electric fluids: the one given out by glass he termed the vitreous fluid; and the other, given out by amber, resin, &c. he termed the resinous fluid, corresponding to the names of those bodies from which they were obtained. Dr. Watson, like most electricians about this period, supposed that the electrical machine gave out or generated the electric matter; but when he discovered that very little electric fire could be obtained from the prime conductor, if the rubber was insulated, or cut off from the earth by a glass pillar, he concluded that the earth, with the conducting bodies surrounding the machine, was the grand reservoir whence the electric matter was derived. This conclusion favoured the idea, that bodies might possess more or less than their natural quantity of the electric matter; for if we allow the assertion, that all bodies contain a certain portion of this fluid within their pores, and that the fluid, which is given out by the prime conductor, is selected by the machine from the earth, and those bodies which surround the machine, it seems highly probable, that bodies which are electrified at the rubber, are deprived of a portion of their natural quantity to supply the machine; therefore, a body electrified at the rubber is said to be electrified minus, while one electrified at the prime conductor is said to be electrified plus, as it is supposed to have acquired more than its natural quantity. A similar discovery was made by Dr. Franklin; and he adopted the same mode of reasoning respecting the source of the electric matter, but used different terms to denote the two states of electrified bodies; saying, that the body electrified at the prime conductor was electrified positively, and that electrified at the rubber was electrified negatively; which terms are still generally adopted. When it was discovered that bodies electrified at the rubber gave the same signs of electricity as those electrified with wax, amber, &c., Du Fay gave up the idea of two electric fluids; and supposed, with Dr. Watson and Dr. Franklin, that the difference between bodies electrified by wax, or at the rubber, and those electrified by glass, or at the prime conductor, depended on their having more or less than their natural quantity of the same fluid, and not on their being electrified with two kinds of electricity. It was at this juncture that Dr. Franklin gave an ingenious turn to these discoveries, which established his fame as a theoretic electrician, although it rendered the subject completely mysterious. Dr. Watson, and the leading electricians of his time, at first supposed, that a Leyden charge consisted of a small portion of the electric fluid retained in the inside of the jar; because the greater part of the fluid, thrown into the jar, appeared to pass through the glass. This simple opinion, respecting the nature of a Leyden charge, was thought satisfactory, while few of its phenomena were known; but when it was proved, that a jar charged positively in the inside gave negative signs on the outside, if placed on an electric stand, it seemed to require some change of opinion to account for this effect: and it was here that Dr. Franklin's ingenuity stept in to supply the apparent deficiency. Dr. Franklin, perceiving it difficult to comprehend how a jar could hold a portion of the electric fluid, if it was admitted that the electric fluid could pass through the glass, concluded that glass was impermeable to the electric matter. Now when the doctor discovered that the outside of a charged jar became electrified with the same kind of electricity as bodies electrified at the rubber of a machine, which he supposed were deprived of their natural quantity of the electric matter, he inferred that the electric fluid must be violently repulsive of itself, and that this repulsive power could pass through the glass, although the fluid could not; therefore, he supposed the electric particles, thrown into the jar while charging, did, by their repulsive nature, repel a certain portion of the electric fluid from the outside of the jar which naturally belongs to that side; consequently, the inside became electrified positively, and the outside negatively.

It is contended, that this state of the two sides is rendered evident by the following experiment: when a jar is insulated, by placing it on an electric stand, so that an uninsulated conducting body can be brought near its outside coating, a quantity of the electric fire will appear to pass from the outside coating to that body, nearly equal to that which is thrown into the jar from the prime conductor, which, it is argued, could not be the case, unless it were repelled from the outside by that thrown into the jar, as the fluid, which is thrown into the jar, cannot, according to Dr. Franklin, pass through the glass. This conclusion is said to be further supported by applying one end of a discharging rod to the outside coating of a charged jar, and the other end of the discharging rod to the knob of the jar ; the supposed redundant fluid in the inside will be so eager to pass to the outside, which is deficient, that a violent explosion will be produced by its efforts to restore the lost equilibrium.

After Dr. Franklin had published his theory, the principle of electrical repulsion was used to solve every electrical difficulty ; yet the principle itself was as mysterious as the effects it was intended to explain.

Although the opinions of Dr. Franklin have been generally adopted, they were never reduced by himself into a concise and systematic form. This, however, has been done by several electricians.

Mr. Epinus, and several other electricians, have been very attentive to this point, and each have given a number of different positions, which are supposed to contain the principles of Dr. Franklin's theory ; but as I conceive the positions which have been published by Mr. Gregory, in his "Economy of Nature," are more correct and consistent with Dr. Franklin's opinions than any other which I have seen published, I shall quote that arrangement for our consideration.

"1st. The electric matter is one and the same in all bodies, and is not of two distinct kinds, "2nd. All terrestrial bodies contain a quantity of this matter.

"3rd. The electric matter violently repels itself, but attracts all other matter.

"4th. Glass, and other substances denominated electrics, contain a large portion of this matter, but are impermeable by it.

"5th. Conducting substances are permeable by it, and do not conduct it merely over their surface.

"6th. A body may contain a superfluous quantity of the electric fluid, when it is said, according to this theory, to be in a positive state, or electrified plus, and when it contains less than its proper share, it is said to be negative, or electrified minus.

"7th. By exciting an electric, the equilibrium of the fluid is broken, and the one body becomes overloaded with electricity, while the other is deprived of its natural share."

By attentively perusing the writings of Dr. Franklin, we shall perceive that the simplicity of his theory is very clear and satisfactory, if it be admitted that the electric fluid possess that peculiar principle of repulsion, which has been ascribed to it by that gentleman; it therefore becomes a matter of considerable importance to inquire how far this supposed principle of electrical repulsion is supported by the test of experiments, and few experiments are better calculated for this purpose, than those made with the double Leyden jar.

It has been asserted, by Dr. Franklin, that for every particle we throw into a jar in charging, a similar particle must leave the outside of the jar, or the jar will not become charged; therefore, if we, for the sake of argument, suppose with Dr. Franklin, that a charge consists of 20 particles, the inside will have acquired by the charge 20 additional particles, and the outside will have lost 20 particles which naturally belonged to that side of the glass, by the repulsive power of those particles which were thrown into the jar. If this statement be correct, what ought to be the result, when we bring the knob of the upper jar A, Fig. 24., to the prime conductor, and attempt to charge it, while the outside of the lower jar B communicates with the earth. According to Dr. Franklin's opinions, I conceive, that if we throw 20 particles into the upper jar A, they will repel 20 particles from the outside of that jar, which will descend into the lower jar B; and that these 20 particles, which pass into the lower jar B, must repel 20 particles from the outside of that jar; consequently, the inside of these two jars will each be 20 particles plus, and their outsides each 20 particles minus: and I conceive it impossible, on Dr. Franklin's theory, that the "*exhausted*" outside of either of these jars can be restored, so long as the fluid, which produced this singular "*exhaustion*," remains within the jar. But instead of this being the fact, if we form a communication between the outside coating of the lower jar B, and even the highest part of the coating belonging to the upper jar A, the whole of the 20 particles, which were repelled from the outside of the jar A, by the fluid thrown into it from the prime conductor, will return to the outside of the jar A, although the fluid which repelled them remains within that jar; and the lower jar B will be instantly discharged, while the upper jar A remains charged. It may be argued that this experiment is not conclusive; because the charge of the lower jar B might overcome for a moment the repulsive power of that fluid within the upper jar A, by its rushing to one point of its coating, in order to complete the circuit; but even this conclusion will not stand the test of experiment: for if the apparatus is dry, and charged as before, we shall find, by the application of small pith-balls, that both sides of the upper jar A will be at the same time in a redundant or positive state of electricity, which appears quite inconsistent with Dr. Franklin's theory. These experiments seem to me so conclusive; that if no other could be advanced, I think we should be justified in doubting the existence of such a principle as electrical repulsion, or at least that it produces those effects which Dr. Franklin has supposed.

Another opinion on which Dr. Franklin's theory greatly depends, is, that the electric matter cannot pass through the best electrics, but can readily penetrate and pass through the interior of the best conducting bodies. This assertion is so at variance with many well known facts, that I think it unnecessary to make many observations to shew its improbability. Light, which can pass through the glass of a Leyden jar with the greatest facility, is impeded in its progress by the finest leaf gold; while the electric fluid, which is so dense as to be retained in glass vessels, is supposed to be capable of passing through the pores of metallic bodies with so little interruption, that it can pass through a circuit of iron wire, some miles in length, with such ease and facility that it does not take up a perceptible portion of time in its passage from one end to the other.

Simple and easy as Dr. Franklin's theory may appear at first view, yet, after a candid and impartial investigation, it will be found to require an assent to principles which are mysterious, and very unsatisfactory, when applied to illustrate many electrical effects. The doctor was so well aware of this, that he candidly acknowledged he could not satisfactorily account why two bodies electrified negatively should repel each other. This difficulty some of his friends have tried to remove; but there still hangs so much obscurity about the explanation, that it does not seem in unison with that simplicity which appears throughout the general economy of nature.

Though Dr. Franklin's opinions have been generally adopted, yet they have met with considerable opposition. The Rev. Mr. Lyons, of Dover, has written professedly to shew the fallacy of Dr. Franklin's theory. This gentleman has endeavoured to prove, by a number of experiments and analogies, that the electric particles are not repulsive of themselves, and that electrics are permeable to the electric fluid; he then attempts to establish a new theory of electricity, still supposing, like Dr. Franklin, that there is but one electric fluid. But, instead of contending for any peculiar principle of electrical repulsion, he ascribes all the phenomena it produces to what he terms the polarity of matter, and supposes that every particle of the electric matter, as well as the particles of all other matter, possesses an inherent "polar virtue," or a power of attraction and repulsion, within itself, which gives rise to all the phenomena of magnetism and electricity. In applying his principles to the illustration of the Leyden experiment, he remarks, that "the Leyden phial, when charged, will always have, like a steel bar rubbed with a load-stone, two different properties or powers; one part will attract, and the other repel an electrified body; and this is probably owing to the electrical particles ranging themselves in glass, as the magnetic particles do in iron and steel in one direction, and upon this principle they attract and repel." He also observes, that, "to charge an electric, the electric effluvia, like the magnetic in a piece of iron, must pass through the substance of that electric in one direction, viz. with their attractive and repulsive parts opposite to each other: it will not charge without it, nor will it discharge unless their opposite parts again meet. All explosions and shocks depend upon this principle, and if the effluvia of the inside and outside of the phial do not unite, neither a spark or a shock will ensue." Although Mr. Lyons has been very solicitous to prove that the electric matter possesses some properties in common with all other matter, yet I conceive he has not pointed out in a clear and satisfactory manner, how this "polar virtue" enables it to produce the electric shock, nor shewn how it makes this fluid move through a circuit of four miles in an instant of time, as proved by the experiments of Dr. Watson and other electricians.

Mr. Morgan, not approving of Dr. Franklin's principle of electrical repulsion, has endeavoured to account for all the electric phenomena by the law of attraction, without the aid of any repulsive power.

This gentleman supposes, that the electric fluid, like matter in general, is subject to the law of attraction, and that all the electric phenomena it produces arise from its attractive qualities. Mr. Morgan, in his Lectures on Electricity, observes, "that the leading principles of our theoretical knowledge, in the science of electricity, are the following:

"1st. The corporeal nature of that something, on whose operations electrical phenomena depend.

"2nd. That the union of that with other bodies depends on an attractive force, or on the mutual attraction subsisting between that corporeal something, which is called the electric fluid, and the body to which it is united.

"3rd. That of the electric fluid there is a certain quantity only retained by different substances; and, moreover, that without some alteration in their constituent parts, it is impossible they should retain more than that certain quantity, or lose any portion of it."

After having contended for the corporeal nature of the electric fluid, which few have denied, he remarks, "that to prove the mutual attraction, subsisting between the electric fluid and other bodies, nothing is necessary but the establishment of its corporeal nature, for, without the capacity of attracting, and of being attracted, it would want one of the essential properties of matter."

Having supposed that every body can retain, by its attractive force, a certain portion of the electric fluid within its substance, but no more than that certain quantity which is called its natural quantity, Mr. M. contends, that when an extra quantity is thrown on one side of an electric body, say the inside of a Leyden jar, that a part of the attractive force of the glass will be drawn off from attracting the fluid it retains, in order to attract this additional fluid thrown upon its inside; consequently it must lessen that attractive force the glass had for its natural quantity, and this loss of attraction extends to every particle naturally contained in the glass; the particles on the opposite, or outside of the jar, therefore, cannot be held by their due portion of attraction, and if any conducting body, that communicates with the earth, is brought to the outside, it will exert a superior attractive force upon the neglected fluid retained near the outside of the jar, and thence conduct it to the earth. On this principle Mr. M. supposes, that a jar becomes negative on the outside, and positive within, without the aid of any repulsive principle; but as he is under the necessity of supposing different degrees of attraction, in different parts of the glass, it renders the action of this attractive principle very complex and difficult to comprehend. Besides, the existence of this principle of attraction is very hypothetical, and I think some facts, which will be mentioned in this Essay will almost prove to a demonstration, that there are two electric fluids materially different from each other.

Mr. Tytler has advanced some very singular opinions on electricity*. This gentleman supposes, that the sun is the source whence the electric fluid is derived, and that it consists of the light emitted from that luminous body; but observes, "that as this fluid receives a great number of different directions after once it enters the earth, it cannot appear in its natural form of fire or light till it receives a new motion, similar to what it had when proceeding from the sun." He also supposes, that the electric fluid is susceptible of receiving two different motions; the one a progressive, and the other a vibratory motion, similar to that given to water, when a pebble enters its surface: he likewise

* Vide Encyclopedia Britannica.

observes, " when by any means it is made to diverge every way from a center, then it operates as heat, expands, rarifies, or burns, according to the intensity of the action. Proceeding in straight and parallel lines, or such as diverge but little, it acts as light, and shows none of that power discoverable in the former case, though this is easily discoverable by making it converge into a focus. In a quiescent state, or where the motion is but little, it presses on the surfaces of bodies, contracts and diminishes them every way in bulk, forces out the expanding fluid within their pores, and then acts as *cold*. In this case also, being obliged to sustain the vehement action of that part of the fluid which is in motion, it flies with violence to every place where the pressure is lessened, and produces all the phenomena of *electricity*."

In considering the difference between conducting and non-conducting bodies, Mr. T. supposes, that " glass and other electric bodies are so constituted, that they can transmit the vibratory motion of the electric matter, though they cannot admit of any considerable progressive one ; conducting substances, on the other hand, admit of a progressive motion, but not so easily of a vibratory one."

After a very extended amplification of these general principles, Mr. Tytler applies them to the illustration of the Leyden charge, and observes, that " when the electric fluid is procured from the earth, by an electrical machine, if the conductor had a communication with the earth, all the matter collected by the cylinder would run along the conductor into the earth ; and not a spark, or other appearance of electricity, would be procured in the air. But, when the conductor is insulated, the matter is forced to go off into the air, and there produce the vibratory motions already mentioned. If a pane of glass, which has no metallic coating, touches the conductor, though it is permeable by the vibratory motion of the electric fluid, yet a considerable resistance is made, and the fluid cannot easily diffuse itself over its surface ; nevertheless, it will soon shew signs of having received electricity, that is, of having the fluid within its pores thrown into a vibratory motion. This motion is directed outwards, from the middle of the substance of the glass to the surface, and a considerable way beyond it on both sides: both sides of the glass are then positively electrified. If a conducting substance touches one of the sides of the glass the vibrations on that side are destroyed, because the fluid which occasioned them yields to the resistance it met with, and runs along the conductor into the earth; but no sooner is this done than the power which resisted the vibration, outward from the glass, having got the better, in the manner just now explained, a new vibration is produced by that resisting power, and the force of this vibration is directed towards the side from whence the electricity was once drawn off, which, therefore, becomes electrified negatively." "Thus, in every charged phial, there is a violent impulse or vibration of the fluid outward from the positive, and inward to the negative side; as long as these continue, the phial continues charged." "The only method of discharging a phial is by making a communication between its coatings; the fluid pressing out of the positive side, now yields to the pressure of that from the negative side, and runs along the conductor; but no sooner does it come near the negative side of the phial, than meeting with more of the same kind, the current of which is directed the same way, both together break through the air with a violent flash and crack, and all appearance of electricity ceases."

This gentleman has displayed through the whole of his remarks a strong and lively imagination, which is highly favourable to the advancement of every theoretic inquiry; but still the importance of his opinions would have been greatly increased, had they been better supported by experiments and analogies.

Mr. Euler has endeavoured to render the science of electricity very simple, by supposing that the electric matter is ether, or that subtile elastic medium which he and some other philosophers have supposed to be diffused throughout the universe. The laws which regulate this elastic medium, in its active state, he conceives to be the same as those which regulate the atmosphere; and concludes, that all the electrical effects produced by this ether, arise from the effort it makes to restore its lost equilibrium. Mr. Euler is likewise of opinion, that we should not be able to discover the electric effects of this agent, if all bodies gave an equal facility to its movements through their pores, and conceives this resistance to be much greater in electric than conducting bodies.

Hitherto we have considered those theories only which are founded on the idea of a single electric fluid; but we shall now have to investigate one founded on the idea of two electric fluids. The difficulties attending Dr. Franklin's theory, induced Mr. Symmer and others to revive the exploded doctrine of Du Fay, that there are two electric fluids; and to adopt the terms used by that philosopher, calling one the vitreous, and the other the resinous electricity.

As Dr. Priestley has given a general, and what I think a very favourable, account of this theory, I shall quote some of his explanatory observations: The doctor observes, "Let us suppose then, that there are two electric fluids, which have a chemical affinity with each other, at the same time that the particles of each are as strongly repulsive of one another. Let us suppose these two fluids in some measure equally attracted by all bodies, and existing in intimate union in their pores, and, while they continue in this union, to exhibit no mark of their existence. Let us suppose that the friction of any electric produces a separation of these two, causing, in the usual method of electrifying, the vitreous electricity of the rubber to be conveyed to the conductor, and the resinous electricity of the conductor to be conveyed to the rubber. The rubber will then have a double share of the resinous electricity, and the conductor a double share of the vitreous; so that, upon this hypothesis, no substance whatever can have a greater or less quantity of electric fluid at different times; the quality of it only can be changed."

"The two electric fluids, being thus separated, will begin to shew their respective powers, and their eagerness to rush into re-union one with another. With whichsoever of these fluids a number of bodies are charged, they will repel one another: they will be attracted by all bodies which have a less share of that particular fluid with which they are loaded, but will be much more strongly attracted by bodies, which are wholly destitute of it and loaded with the other; in this case they will rush together with great violence. Upon this theory every electric spark consists of both fluids, rushing contrary ways and making a double current. When, for instance, I present my finger to a conductor loaded with the vitreous electricity, I discharge it of part of the vitreous, and retain as much of the resinous, which is supplied to my body from the earth. Thus both the bodies are unelectrified, the balance of the two powers being perfectly restored.

"When I present the Leyden phial to be charged, and, consequently, connect the coating of one of its sides with the rubber, and that of the other with the conductor, the resinous electricity of that side which is connected with the conductor, is transmitted to that which is connected with the rubber, which returns an equal quantity of its vitreous electricity, so that all the vitreous electricity is conveyed to one of the sides, and all the resinous to the other. These two fluids, being thus separated, attract one another very strongly through the thin substance of the intervening glass, and rush together with great violence, whenever an opportunity is presented, by means of proper conductors. Sometimes they will force a passage through the substance of the glass itself; and, in the mean time, their mutual attraction is stronger than any force that can be supplied to draw away either of the fluids separately." "All the vitreous electricity being thus brought to one side of the plate of glass, and all the resinous to the other, the phenomena of the plate while standing charged, or when discharged, are perhaps more free from all difficulty than upon any other hypothesis. When one of the sides of the glass is conceived to be loaded with one kind of electricity, and the other side with the other kind, the strong affinity between them, whereby they attract each other with a force proportioned to their nearness, immediately supplies a satisfactory reason, why so little of either of the fluids can be drawn from one of the sides without communicating so much to the other. Upon this supposition, that consequence is perhaps more obvious, than upon the supposition of one half of the glass being crouded with electric matter, and the other half exhausted. In the former case, every attempt to withdraw the fluid from one of the sides is opposed by the more powerful attraction of the other fluid on the opposite side; on the other hypothesis, it is only opposed by the attraction of the empty pores of the glass. Lastly, the explosion upon the discharge of the glass has as much the appearance of two fluids rushing into union in two opposite directions, as of one fluid proceeding only in one direction."

This theory has since been applied to the illustration of the electric phenomena, in a very able and accurate manner, by the learned M. R. J. Haüy, in his elementary treatise on natural philosophy; but still it remains very complex and difficult to comprehend; for he remarks, when speaking about the nature and laws of the electric fluids, "that the moleculæ of each mutually repel one another, while they attract those of the other fluid. Hence there results four different combinations of actions between the fluids of two bodies, namely, two repulsions and two attractions; and on these depend the motions, by which the bodies themselves approach or recede one with regard to the other."*

Mr. Adams has been particularly attentive to this theory, and, in his Essay on Electricity, has given the following positions, as containing its general principles:

"1st. The two electric powers exist together in all bodies.

"2nd. As they counteract each other when united, they can be rendered evident to the senses only by their separation.

"3rd. The two powers are separated in non-electrics by the excitation of electrics, or by the application of excited electrics.

* Gregory's Translation of Haüy's Natural Philosophy, p. 348.

"4th. The two powers cannot be altogether separated in electrics.

"5th. The two electricities attract each other strongly through the substances of electrics.

"6th. Electric substances are impervious to the two electricities.

"7th. Either power, when applied to an unelectrified body, repels the power of the same sort, and attracts the contrary."

The propriety and truth of these positions Mr. Adams has endeavoured to establish, through the whole of his Essay, by a number of experiments and analogies; but in his Lectures, which is a later publication, he has varied from these opinions considerably. In this last-mentioned work, Mr. A. contends for the identity of light, fire, and electricity; he supposes that electrics are permeable to the electric fluids; yet, at the same time, asserts, that when a Leyden jar is charged, one side is charged with the vitreous, and the other side is charged with the resinous, electricity; and that the singular state of the inside and outside of a charged jar is produced by those peculiar principles of attraction and repulsion, which have been ascribed to these fluids. In my opinion, the same objections as have been adduced against Dr. Franklin's scheme of electrical repulsion, may, with equal force, be brought against this theory; besides, its complexity appears quite inimical to that simplicity to which science in general seems rapidly advancing.

Dr. Peart has published a small essay, in which he has differed from these opinions, although he is an advocate for two electricities. He supposes that one fluid consists of ether, and the other of phlogiston; but as the existence of ether and phlogiston is still so very hypothetical, Dr. P.'s reasoning on this subject cannot be considered as conclusive.

Messrs. Lovett, De Luc, and Bennett, have supposed the electric fluid to be a compound, the finer part of which can pass through electric bodies; and that, when a jar is charged, the thinnest part of the compound passes through the glass, while the grosser part is retained in the jar. This opinion appears so objectionable, and so contrary to experiments, that I think it unnecessary to trouble the reader with any other observation, but shall proceed to consider the subject in quite a new point of view.

If an attentive consideration be given to the general view which I have taken of the subject, it must appear evident to an impartial mind, that our present theories are very unsatisfactory, when applied to illustrate many electrical appearances. This reflection has induced me to attempt to revive and carry forward some of those simple, and what have been called unphilosophical, opinions which obtained about the year 1747, although they have remained nearly unnoticed since that period.

I think it probable, that Dr. Watson and Du Fay would not have abandoned their early notions on electricity, had they been favoured with those experimental facts which we possess at this time, but would have greatly extended the sphere of our theoretic knowledge on just and rational principles. After having observed the different windings, through which the imagination has led the votaries of this science, since the period to which I allude, the inquiring mind will remain unsatisfied, and will naturally be disposed to resume the subject at that point of time when the conclusions of electricians were regulated by the evidences of their senses, instead of being carried away by the plausibility of ingenious conjectures. If we reject the obscure principles adopted at the present day, and substitute a more plain and simple mode of investigation, our theoretic attainments may not perhaps appear to advance with that rapidity we could wish; still if they are consistent with experiments, and partake of a greater share of simplicity, I trust they will be of far more importance, (as they may lead to the establishing of a true electric theory,) than any specious conclusions which can be derived from the mysterious principles ascribed to electric matter.

Being convinced of the difficulty that must attend a clear developement of the laws that regulate the electric fluids, however judiciously the subject may be treated, I am induced to offer a few positions, containing a general view of those principles, on which all my future observations will be grounded. It is hoped that these positions will be found consistent with that simplicity I have mentioned, and independent of those mysterious laws and qualities which support all our popular theories.

POSITIONS.

1st. There are two electric fluids, which are composed of caloric and the constituent parts of the atmosphere. In the excitation of electricity by the electrical machine, the air is decomposed, its two gases are more closely united to caloric, or matter of heat, by the attrition of the cylinder and rubber, and constitute two distinct electric fluids.

2nd. These fluids can pass through the best electric bodies, but cannot pervade the interior of good conducting substances, though they can pass along the surface of the latter with inconceivable ease and velocity.

3rd. When an electric body is charged, for example, a pane of glass, or a Leyden phial, a small portion of the electric fluid is retained on one side of the charged electric; which, in the act of discharging, excites a considerable portion of fresh electricity, and gives birth to the most singular part of the Leyden phenomena.

There are three points in which the opinions contained in these positions differ very materially from those generally adopted:

Most electricians have asserted, that the electric matter is universally diffused throughout the earth and atmosphere; but, by the first position, the electricities we bring into action by the electrical machine, can only be considered occasional agents, or new compounds, formed by the attrition of the cylinder and rubber.

It is asserted, that the electric matter cannot pass through good electric bodies, as glass, &c.; but that it can pass through the pores of the best conducting bodies, as metals, &c. with the greatest facility. According to the second position, it cannot pass through the pores of the best conducting bodies, but can pass through the best electric bodies.

It is also asserted, by most writers on this subject, that when one side of a Leyden jar is charged with positive or vitreous electricity, the other side *must* be charged with the negative or resinous electricity. But from the third position we may infer that one side of an electric can be charged, while the opposite side remains in its natural state of electricity.

As these conclusions are so at variance with what are considered by many as established opinions, it seems highly necessary that some reasons should be advanced in their support. This I shall endeavour to accomplish, by making a few remarks on each position separately. In the investigation of a subject so intricate as the present, we cannot judge how far any opinions are worthy of consideration, by taking a partial view of the inquiry. It is only by a general view of electrcial facts, and a strict attention to analogies which can be drawn from other branches of natural philosophy, that we can make a just estimate, or come to any satisfactory conclusion, respecting their propriety.

One of the first questions induced by the above positions is, What ground is there for supposing that the electric fluids are new compounds, formed of caloric and atmospheric air?

Many authors, who have given an opinion respecting the nature of the electric matter, have supposed it to be elementary fire or caloric, or at least caloric enters into its combination. The late Mr. Adams, in pointing out the similarity between the action of the electric matter and elementary fire, observes, "it will light a candle, fire gun-powder, and throw metals into a violent fusion, and dilate all bodies; it will also promote vegetation, and accelerate evaporation, as well as elementary fire:" therefore, it appears probable, that caloric or elementary fire is in some measure combined with the electric matter.

Although many instances may be adduced to shew that there is a strong resemblance between the action of elementary fire, and that of the electric matter, yet in other cases there is so great a difference between their laws of action as completely to prove they are not the same agents. It is well known to all electricians, that the electric matter is so rapid in its movements, that it will pass from one end to the other of an iron wire, many hundred yards long, in an instant of time; while caloric, in its most active state, will take up a sensible portion of time in passing along a few inches of the same wire; therefore, there can be little doubt but they are essentially different. Although Mr. Adams, as well as several other writers, has contended for the identity of elementary fire and electricity, yet in his essay he remarks, "Though the electric fluid has been studied for many years, we are altogether ignorant of its real nature; to me (he observes) it seems probable, that it is fire or light connected with some terrestrial base;" but he does not give us the least intimation of what that terrestrial base consisted.

I have stated that there are two electric fluids, which are composed of caloric and the constituent parts of the atmosphere. The circumstances already mentioned shew the probability that caloric enters into their combination; and, it has been shewn by several experiments, that electricity cannot be excited, when the exciting apparatus has no access to atmospheric air. A respectable scientific gentleman, in London, has made a well-arranged experiment, the result of which appears highly favourable to this opinion; he so constructed an electrical machine, as to be able to work it in a torricellian vacuum, and found the machine would not produce the least electricity, when cut off from the atmosphere. When mercury is agitated in a glass tube, in which a portion of air is included, electrical signs are evinced by the action of the mercury against the sides of the glass; but, if the tube is completely deprived of air, the action of the mercury on the sides of the glass does not produce those electrical appearances. These results would be of little consequence, if they were not supported by other experiments, as it may be argued that electricity is produced when the exciting apparatus has no access to the atmosphere, and only wants the air to put it in motion and render it manifest.

If the rubber and prime conductor of an electrical machine are both insulated, and a pointed wire made to project from each, as AA, Fig. 25. a continual stream of electricity will flow from each point, as long as the machine is kept turning. This fact is shewn by the motion of two small paper vanes. These vanes are made by sticking strips of paper into the sides of two small corks, and passing through the corks two small needles, which are suspended by the magnets B B, and serve for the two axis round which the vanes turn. When the ends of the vanes are brought near the points of the wires, their rotation will shew that a stream issues from each wire; and this motion will continue as long as the machine is kept in action.

To this experiment it may be remarked, that the surrounding atmosphere may supply the machine with electricity, without supposing the air constitutes any part of the electric matter; or, that the fluids, which are given out at these wires, may be derived from the earth by the imperfect insulation of the glass pillars, which support the rubber and prime conductor: but what militates against the force of such remarks, is, that the electricity given out by each pointed wire *increases* in *proportion* to the non-conducting power of the atmosphere, and the increased insulation of the rubber and prime conductor.

This experiment with the vanes is not the only one that can be made, to shew that a stream of electric matter flows from each pointed wire, while the machine is in action. When either the rubber or prime conductor is insulated, and a bit of sealing-wax placed upon the pointed wire, light it with a candle, and a quantity of small wax threads will be projected from the point by the fluid: if a piece of paper is held near the point, it will receive these threads, which make a curious configuration on the paper. Some electricians have supposed, that the stream issuing from the pointed wire projecting from the rubber, consists of air which has been deprived of its natural share of electricity to supply the machine, and is flying off to restore its lost equilibrium; but, however ingenious this supposition may appear, still it seems very complicated and difficult to understand.

It has been generally asserted, since the discoveries of Dr. Watson, that the earth is the grand reservoir from which we draw the electric matter; and that the rubber must communicate with the earth by a good conducting body, in order to enable the machine to give out a proper quantity of electricity.

In my opinion it is not necessary that the rubber should have a good communication with the earth, in order to collect a regular supply of electric matter from that supposed reservoir; but to enable it to part with the superabundance of resinous electricity it receives from the action of the cylinder, which, if retained, predominates over any fresh excitation, and thus prevents the conductor from giving out its proper quantity of vitreous electricity.

The reasons that induce me to draw this conclusion, are derived from the experiments I have mentioned with the wax and paper vanes, as they support, in a direct manner, the idea, that the atmosphere is the source whence the machine is supplied with the electric matter.

That atmospheric air forms a part of these electric fluids, is strongly supported by several analogous facts, as well as the experiments I have just mentioned.

It is now well ascertained, that the atmosphere, generally speaking, is composed of two gases, which can be separated by several chemical operations, and that the base of one, which is termed oxygen gas, forms a part of most acids, consequently of an acid nature; and that the other, which is termed nitrogen gas, forms a part of the volatile alkali, consequently of an alkaline nature. When an infusion of litmus is exposed to the action of an acid, which contains the oxygen of the atmosphere, its colour becomes changed from a purple to a red; and if again exposed to the action of an alkaline mixture, which contains the nitrogen of the atmosphere, it is restored to its former colour. We now come to an analogy which I think favours the above opinion in a very powerful manner.

Dr. Wollaston observes, "Having coloured a card with a strong infusion of litmus, I passed a current of electric sparks along it, by means of two gold points touching it at the distance of an inch from each other. The effect, as in other cases, depending on the smallness of the quantity of water, was most discernable when the card was nearly dry. In this state, a very few turns of the machine were sufficient to occasion a redness at the positive wire, very manifest to the naked eye; the negative wire being afterwards placed on the same spot soon restored it to its original blue colour."*

Several other analogies of this kind might be mentioned; but this supports the idea, that atmospheric air forms a part of the electric fluids, so directly, that it can hardly fail of inducing a further inquiry into this part of the subject. As we find that the prime conductor gives out the electric fluid which contains an acidifying quality, and the rubber that which contains an alkalizing quality, we may justly infer, if we admit they derive these properties from the air, that it is decomposed by the action of the machine at the point of excitation, as its constituent parts never give the above results till separated.

The next position, that these fluids can pass

* Phil. Tran. 1801.

through the best electrics, but cannot pervade the interior of good conducting bodies, though they can pass along the surface of the latter with inconceivable ease and velocity, is in opposition to the present received opinion; as it is generally affirmed, by most electricians, that the electric matter can readily pervade the pores of good conductors, but cannot permeate good electric bodies. The idea that glass, and other electrics, are impermeable to the electric matter, chiefly originated with Dr. Franklin; and we may gather from his letters the reason that induced him to come to this conclusion. The doctor says, when speaking about the Leyden charge, that, "To a slight observer, the electric matter does appear to pass through the glass;" but remarks, "if that was the case, how could the bottle hold a charge?" Hence it seems evident, that the impermeability of electric bodies to the electric fluid was suggested by the difficulty attending an illustration of the Leyden experiment; but, in my opinion, it required no such conclusion to obviate that difficulty. Few experiments are more in favour of the permeability of electrics than the following:

Let a jar be charged, taking notice of the quantity of sparks that pass into the jar while charging;

when charged, place it on an electric stand, and bring an uninsulated conducting body to the knob of the jar; that body will receive a small portion of electricity from the knob, the inside of the jar will be discharged, and the outside become charged.

It has been contended, that, in this case, the inside of the jar is not deprived of all the electricity it received from the prime conductor; but, as in all other cases, communicated electricity eagerly escapes to the earth when it meets with an uninsulated conducting body, I shall not, for the sake of any hypothetical conjecture, suppose, that it violates that general rule in this instance; but conclude, agreeably to the evidence of our senses, that, under these circumstances, the inside of the jar is discharged, and that the charge the outside acquires at the time, is a distinct charge, which will come under our consideration when we enter more minutely into the nature of the Leyden experiment.

Mr. Wilson found, if the bottom or side of a Leyden jar was ground very thin, and covered with sealing-wax till charged, then the sealing-wax taken off, and an uninsulated conducting body brought in contact with the thin part of the glass, that the charge was dissipated in about half the usual time ; a circumstance which appears highly favourable to the permeability of glass by the electric matter.

The next position, that when an electric body is charged---for example, a pane of glass, or a Leyden jar---a small portion of the electric fluid is retained on one side of the charged electric, which, in the act of discharging, excites a considerable portion of fresh electricity, and gives birth to most of the Leyden phenomena, is so directly supported by the above experiments, that I think it unnecessary to make any other observation on this position till we come to the particular illustration of an electric charge.

An experiment has been made by Mr. Cuthbertson, and another by Mr. Lullin, of Geneva, which seem, at first view, to militate much against the idea of two electricities. But Mr. Tremery, a French philosopher, has made an experiment which places them in a very different point of view, and gives additional proof of there being two electric fluids.

The experiment related by Mr. Cuthbertson is made in the following manner: insulate two wires, each furnished with a brass ball, three quarters of an inch in diameter; connect one with the positive, and the other with the negative, conductor; the balls should be about four inches asunder, and between them, at equal distances from each, place a lighted candle, with the centre of its flame on a level with the centre of the balls; when the machine is powerfully excited, the flame will waver very much, and seem to incline rather more to the negative ball than to the positive one: after about fifty revolutions, the negative ball will grow warm, and the positive remain cold; if the revolutions are continued, the negative ball will be too hot for the hand to touch, but the other will remain cold---strongly indicating that the current passes from the positive to the negative conductor.

Mr. Lullin made a very curious experiment, which appears equally decisive in favour of there being but a single electric fluid.

This may be readily made by the universal discharger, Fig. 18. Take the knobs off the directing wires, place a card on the stand in the middle of the apparatus, slide the end of that directing rod, which is to communicate with the outside of the jar or battery, under the card; then place the end of the other wire, which is to form a connexion with the inside of the jar, upon the card, at about an inch distance from the end of the negative wire; and when a discharge is made, the fluid will pass from the wire, connected with the inside of the jar or battery, and perforate the card just over the point of the negative wire, clearly shewing, that the charge passed over the card from the positive to the negative point. Mr. Tremery has investigated this result, and a discovery arose from the investigation highly favourable to the idea of two electric fluids.

He so constructed an apparatus, that he could place the conducting wires and card under the receiver of an air-pump, and found, as the receiver became exhausted, that the point of perforation receded from the end of the negative wire towards the end of the positive one; and, at a certain exhaustion, the card was perforated exactly in the centre, between the ends of the two wires*; but when he permitted the air to re-enter the receiver by small portions, he found at each explosion the point of perforation returned towards the end of

* Vide Haüy's Natural Philosophy, translated by Gregory.—Vol. I. p. 410.

the negative wire in proportion to the quantity of air admitted.

It will be difficult to explain this result on the hypothesis of a single electric fluid; but it is readily understood, if we admit that there are two electric fluids, one of which can pass through the atmosphere with more facility than the other. This discovery furnishes an easy solution to the experiment with the two balls and lighted candle; for the vitreous or positive fluid being capable of passing through the air with greater facility than the resinous or negative fluid, it follows, that the current must pass from the positive to the negative ball, and, consequently, carry the heat of the candle in that direction.

The luminous appearance at electrified points has been thought a considerable objection to the idea of two electricities. A pointed wire projecting from a conductor, electrified positively, will throw out many branching streams of electric fire; while the streams of electric fire, at a pointed wire, projecting from a negative conductor, are so contracted, that they appear at a little distance, as a lucid point of light; but the discovery of Mr. Tremery intimates the cause of this difference.

It has not been a very difficult task to make these general remarks on the nature of the electric fluids; but to shew the particular laws by which they produce so many strange electrical results, will require considerable care and attention.

As the phenomena attending the Leyden experiment are the most difficult to explain, and have been investigated with more interest by electricians than any other, it is of the first importance, in a theoretic point of view, to inquire how far the new principles advanced will enable us to illustrate these effects; and I have no doubt but the reader will exercise a due portion of candour, through every part of the investigation, when the difficulty of the subject is taken into consideration.

Instead of contending that the electric fluids are regulated by mysterious laws, I shall consider their action as consonant to those general laws which regulate all other elastic mediums. After having abandoned the idea that these fluids possess any peculiar laws of attraction and repulsion, let us suppose, with the electricians of 1746 and 1747, that the greater part of the fluid, which is thrown into a jar while charging, passes through the glass to the earth, and that a charge consists of a small portion which is retained within the jar.

I am well aware it will be difficult, when first stated, for the mind to conceive how a jar can retain a small portion, if it be admitted that the fluid can pass through the glass ; I shall, therefore, mention an éxperiment made with a small quantity of mercury, as it may assist us in the investigation, though it may not be considered strictly analogous.

Take a glass tube, of about an inch bore, and 12 inches long, tie over one of its ends a piece of thin gauze ; hold it in a perpendicular direction, and pour into the other end, through a small funnel, a certain quantity of mercury. The greater part of the mercury, by its impetus, will pass through the gauze, while a small portion will be retained within the tube. It is rather singular that this experiment with the mercury and gauze should, in some of its variations, agree with several circumstances that attend the Leyden experiment ; for, supposing the mercury detained in the tube equal to a dram, we shall find, if thinner gauze be used a greater quantity of mercury must be poured into the tube, in order to detain a dram ; and when the gauze used is too thin and open, the whole of the mercury will pass through it. Now it is a well known fact, respecting the Leyden charge, that the thinner the glass, provided it is not too thin, the greater quantity of electricity must be thrown into the phial before the detained fluid arrives at a certain intensity, as shewn by the quadrant electrometer, and, when the glass used is too thin, the whole of the fluid thrown into the phial will pass through it " like water through a sieve."*

The experiment with a single Leyden jar, mentioned in page 104, renders it pretty evident, that the greater part of the fluid, which is thrown into a jar, does, by its impetus, pass through the glass :

Charge a small jar, observing the quantity of fluid that will pass into the jar from the prime conductor while charging; then place it on an electric stand, as Fig. 26. and bring an uninsulated brass ball to the knob; that ball will receive a very small portion of fluid, compared with the quantity which passed into the jar, and the inside will be discharged, but the outside will become charged with the contrary electricity. It has been

* Priestley Hist. Electricity.—Vol. II. Page 247.

remarked, that the inside of the jar is not discharged in this case ; for, as the outside is said to be in a state of deficiency, it is supposed the inside cannot part with its superabundance till that deficiency is supplied from the earth, which the outside is prevented from receiving by the electric stand; but as the experiments made with the double jar clearly shew, that the electric matter does not possess any peculiar principle of repulsion that keeps the outside deficient, I shall suppose that the whole of the charge quits the inside of the jar when the uninsulated conducting body is brought to its knob, and that the contrary fluid, which obtains on the outside of the jar, is a fresh portion of electricity generated at the time the vitreous fluid left the inside.

This statement naturally gives rise to the question, whence comes that portion of the resinous fluid which charges the outside of the jar, when the inside is discharged by an uninsulated brass ball, while the jar is placed on the electric stand? That the resinous electricity, here mentioned, is a fresh portion, generated by the mechanical force of the vitreous fluid, which constituted the charge, and passed off by the brass ball I have little doubt; but as it was excited so instantaneously, that we cannot discover, by any inspection, what takes place at the knob of the jar when this change is produced, we must have recourse to the aid of analogy to enable us to form just conceptions of this singular circumstance.

As I have supposed the result depends on fresh electricity, excited in a particular manner, I shall endeavour to shew what a small degree of action among the particles of matter, will produce or generate these fluids.

It has been asserted, by very able writers, "that air is excited by every circumstance that puts its particles in motion." Mr. Morgan informs us, that whenever a solution or precipitation takes place, electricity is produced or excited; and, by the experiments of Professor Ritter, of Munich, it appears that the current of magnetism, flowing from a magnetic battery, is sufficiently powerful to generate or bring into action these fluids; hence it would not be extravagant to conclude, that the smallest particles of matter, when put in motion, become exciters of electricity. If we bring an excited glass tube near the small insulated conductor, as Fig. 27., we shall perceive, by the pith balls, which are suspended by silk lines, that the conductor and balls will become electrified with the same kind of electricity as that of the glass tube, which seems a very probable result; but if we bring the excited glass tube to one end of the conductor, and the uninsulated brass ball to the other end, at the same time, as Fig. 28., and then immediately remove them from the conductor, we shall find that the balls and small conductor will be electrified with the resinous fluid, contrary to the former experiment. The reason of this difference may appear rather obscure, till we have given a little attention to this last result.

It will not be difficult to conceive, why the conductor and balls were charged with vitreous electricity, in the first instance; for the fluid possessed by the tube being vitreous, it necessarily imparted that kind to the small conductor. But, in the second instance, when the brass ball was held to the opposite end of the small conductor, the vitreous fluid, which was communicated to the small conductor by the tube, would readily pass off by the brass ball to the earth. Now, as there was no other known agent in motion, in this experiment, than the vitreous fluid from the glass tube, we may fairly infer, that it did, by its momentum, when passing from the small conductor to the brass ball, excite fresh electricity, which separated at the point of excitation ; consequently, all the vitreous fluid passed off by the brass ball to the earth, while the resinous passed to the small insulated conductor, and electrified the pith balls. It is contended, by the friends of Dr. Franklin's theory, that in this experiment the electricity naturally belonging to the small conductor is repelled into the brass ball by that of the tube, and when the tube and brass ball are removed, the small conductor is left in a state of deficiency, or charged negatively. But as this illustration depends on a supposed peculiar principle of repulsion, which the experiments with the double jar shew these fluids do not possess, I shall not make any remark on that opinion, but apply the principle here developed to the illustration of the Leyden experiment. In the former part of the investigation, a Leyden jar had been charged with vitreous electricity, and placed on the electric stand ; the inside was discharged by the brass ball, and the outside had become charged with the resinous electricity. If the experiment with the small conductor and brass ball be analogous, we may conclude, that the small portion of vitreous fluid, which was retained as a charge in the inside of the jar, and carried to the earth by the brass ball, did, by its impetus in passing to the brass ball, excite fresh electricity, which separated at the point of excitation; therefore, agreeably to the experiment with the small conductor, all the vitreous fluid passed by the ball to the earth, while the resinous rushed into the jar, which, by its impetus, passed through the glass to the outside coating; but as that coating was insulated by the electric stand, it could not escape to the earth; and, having lost the momentum by which it passed through the glass, it could not return into the jar; consequently, the outside of the jar became charged with a small portion of resinous electricity. If the brass ball be now applied to the outside coating, it will receive a small portion of the resinous fluid from that coating; the outside of the jar will be discharged, and the inside again become charged with a small portion of the vitreous fluid. A similar reason may be assigned for this as was given for the former result.

When the uninsulated brass ball was brought near the outside coating, the resinous fluid on the outside of the jar rushed to that ball, and, by its momentum, when passing from the outside of the jar to the ball, excited fresh electricity, which separated at the point of excitation; the resinous part of which passed to the earth by the brass ball, while the vitreous, agreeably to the last experiment, and that with the small conductor, rushed to the outside coating of the jar, and, by its impetus, passed through the glass; but, as the inside of the jar was insulated, it could not escape to the earth, and, having lost the impetus by which it passed through the glass, could not return; consequently, the inside again became charged with a small portion of vitreous electricity. Although these alternate chargings and dischargings of the two sides gradually become weaker, yet they may be repeated a great number of times before the whole of the fluid is dissipated. When the jar and stand are fitted up with pith balls, as Fig. 29., each pair of balls will open with fresh electricity a hundred and fifty or two hundred times, if the knob and outside coating are alternately touched with an uninsulated conducting body. Besides this mode of discharging a jar, there are others which produce a very different effect: let the same jar be charged with the vitreous fluid to a similar intensity, and placed on an electric stand, as in the last experiment, but before the brass ball is brought to the knob of the jar, let an uninsulated conducting body be placed about a quarter of an inch from its outside coating; then bring the brass ball to within the same distance of the knob of the jar, and there will be two streams of electric fire induced, one passing between the conducting body and the outside coating, and another between the brass ball and the knob of the jar, which very soon produce a discharge. In this experiment a much greater quantity of electric fire will pass from the knob of the jar to the brass ball, than passed to the brass ball when brought to its knob in the former experiment; therefore, if it is not admitted, that fresh electricity is excited in the discharge of a jar, it will be very difficult to reconcile the appearance of this discharge with the former.*

* The uninsulated conducting body I use in this experiment, which may be termed a conducting rod, consists of a brass-jointed rod, ball, and stand, as Fig. 30.; this apparatus being made with a joint in the middle of the rod will be found very convenient in many electrical experiments, when a communication with the earth is necessary. In Fig. 31. the upper part of the rod is insulated by the glass pillar A, which is fitted up with a pair of pith balls, and is extremely convenient for collecting a small quantity of electricity from any electrified body, when we wish to know what kind of electricity that body possesses.

In the first experiment the jar was charged and placed on the electric stand, the brass ball then brought to the knob of the jar; that ball received a comparatively small portion of electricity, and the inside of the jar was discharged; as this was the fact, whence comes that extra quantity of electricity, in the second mode of discharging the inside of the jar, if no fresh electricity is excited in the discharge?

These different results are consonant to the principles asserted in this Essay.

In the first mode of discharging, one conducting body only was used, which was applied to each coating alternately, and rendered the new excitations slow, as shewn by the great number of alternate chargings and dischargings of the two coatings. But, in this last mode of discharging the jar, a distinct conducting body was applied to each coating, which induced the alternate excitations so rapidly, as to appear like two streams of electricity, one passing between the outside coating and conducting body, and another passing between the knob of the jar and the brass ball, which quickly discharged the two sides of the jar.

Another mode of discharging the jar is, by inducing the whole of these alternate excitations to explode at one point, and at the same instant of time. This effect is produced by placing one knob of the common discharging rod (Fig. 15.) upon the outside coating, and bringing the other knob of the discharging rod to the knob of the jar. The stream of electricity, which passed in the last experiment to the earth from the outside coating, will now rush along the bow of the discharging rod towards the knob of the jar, where it will meet with a portion of fresh excited vitreous electricity, flowing from the knob of the jar; and these streams of fresh excited electricity, by moving in contrary directions, will rush upon each other with such violence, that a considerable quantity of caloric will be liberated from them by their concussion, and the atmospheric equilibrium immediately restored.

The principles here laid down, and the explanation given of the Leyden experiment, will enable us to illustrate several electrical effects which have embarrassed all other theories.

Let two small jars, of equal capacity, the glass of one being double the thickness of the other, be fitted up in the usual manner; charge these jars to the same intensity, as shewn by fixing a quadrant electrometer to the prime conductor; when they are discharged, the explosion of the thin jar will be found nearly double the strength of the other, although both jars were charged to the same intensity. To accommodate this result to the received theory, it has been supposed there was more electric matter in the thin jar than in the thick one, and that it was prevented from affecting the electrometer, in proportion to its accumulation, by the electrical exhaustion of the outside; but as the electrometer is used in all other cases to shew the intensity of communicated electricity, I shall suppose that in this instance it gives correct signs, and not for the sake of any theoretic convenience forsake this general criterion, but conclude, that the charges were of the same strength notwithstanding the discharges were so very different.

If the greater part of the fluids brought into action in a discharge, are derived from a number of fresh excitations, which alternately pass through the glass when a jar is discharged, we are furnished with a very easy solution to this result; for a greater portion of these fresh excited electricities must pass through the thin jar than can permeate the thick one; and, as these portions can pass through with more facility, they must each act with more force on the brass ball and uninsulated conductor, consequently, by their increased momentum, excite a larger portion of electricity than could be the case if the glass were thicker; should this be admitted, we shall be enabled to understand, why a thin jar gives a much stronger discharge than a thick one, although they are both charged to the same intensity, as shewn by the quadrant electrometer, without forsaking the general rule, that the elevation of the electrometer shews the quantity of communicated electricity.

The experiment of charging a plate of air is very difficult to reconcile to the popular theories; for although it has been contended, that glass and most other electrics are impermeable to the electric fluid, yet it never has been argued, that air, which is an electric, and capable of being charged, is impermeable to these fluids. From several effects we may fairly conclude, that a charge belonging to a plate of air is in contact with the upper board, Fig. 23., and resides on the surface of the air included between the two boards, and, when the uninsulated brass ball is brought to the upper board, that the fluid, which forms the charge, rushes to the uninsulated body, and by its impetus excites fresh electricity, which separates at the point of excitation, like that excited in the discharge of a Leyden jar, the vitreous part of which passes by the brass ball to the earth, while the resinous passes to the upper board, and by its impetus rushes through the plate of air to the lower board, which is insulated, therefore this fluid cannot escape to the earth ; consequently, that board, and the under side of the plate of air, become charged with a small portion of the resinous fluid. When the uninsulated brass ball is brought to the lower board, it becomes discharged, and the upper one again charged with a small portion of the vitreous fluid, as shewn by the suspended pith balls b b, which proves that the charge and discharge of a plate of air depend on the same principles as the Leyden experiment.

Mr. Atwood charged an electric plate very slightly, and when it was insulated, and an interrupted circuit formed between the two coatings, the two currents became visible, by illuminating the interrupted points in the circuit, the illumination extending further from each surface in proportion to the strength of the charge ; but when the charge was increased, to make the illuminations meet in the middle of the circuit, an explosion of the whole charge immediately took place; the length of the circuit used by Mr. Atwood was about 12 feet.

Mr. Symmer passed several powerful charges through a quire of paper, and always found the edges of the paper, round the perforation, bent in opposite directions from the centre.

"In the middle of a paper book, of the thickness of a quire, Mr. Symmer put a slip of tin-foil; and in another, of the same thickness, he put two slips of the same sort of foil, including the two middle leaves of the book between them; upon striking the two different books the effects were answerable to what he expected: in the first, the leaves on each side of the foil were pierced, while the foil itself remained unpierced; but, at the same time, he could perceive an impression had been made on each of its surfaces, at a little distance from one another, and such impressions were still more visible on the paper, and might be traced as pointing different ways. In the second, all the leaves of the book were pierced, excepting the two that were between the strip of foil; and in these two, instead of holes, the two impressions, in contrary directions, were visible."

Although the principles advanced may enable us to account for these and most of the electrical phenomena, in a more satisfactory manner than any other theory, yet it must be obvious, that several questions may arise to which it will be difficult to give an immediate answer. It may be asked, by what law do these fluids separate, and flow in different directions from the point of excitation, and what proportion do the constituent parts of the atmosphere bear to the caloric in these new compounds? With respect to the first, I should ascribe the effect, in part, to the law of aggregation; and the latter is rather more a chemical than an electrical question; however, I think it extremely probable, that the quantity of atmospheric air bears a very small proportion.

In this Essay I have been solicitous to establish these opinions, that the electric fluids are derived from the atmosphere, and are not universally diffused through all bodies, as is generally believed by electricians, but are only occasional agents, produced by the collision or friction induced among the particles of matter, and that their laws are agreeable to the laws which regulate all other elastic mediums.

Should the evidence advanced in this Essay be thought sufficiently strong to warrant the conclusion, that atmospheric air forms a part of these electric fluids, it opens a wide field for speculation.

In chemistry the fact seems highly desirable, as there appear many obscure results, which the occasional existence of agents like these may tend to illustrate; but when we turn to the silent work of vegetation, the view at once becomes extensive and sublime! The constituent parts of the atmosphere are known to form a considerable part of all vegetables, and if it be true that the rays of the sun* have the power, as well as the rising and falling vapours, to generate these fluids, how extensive must be their formation, and how admirably they seem adapted, by their activity, to promote the vegetable process by which they are again most probably decomposed, and a part of their atmospheric portion retained for the growth of vegetation.

* See Boyle's Works, abridged by Shaw, Vol. I. page 400.

THE END.

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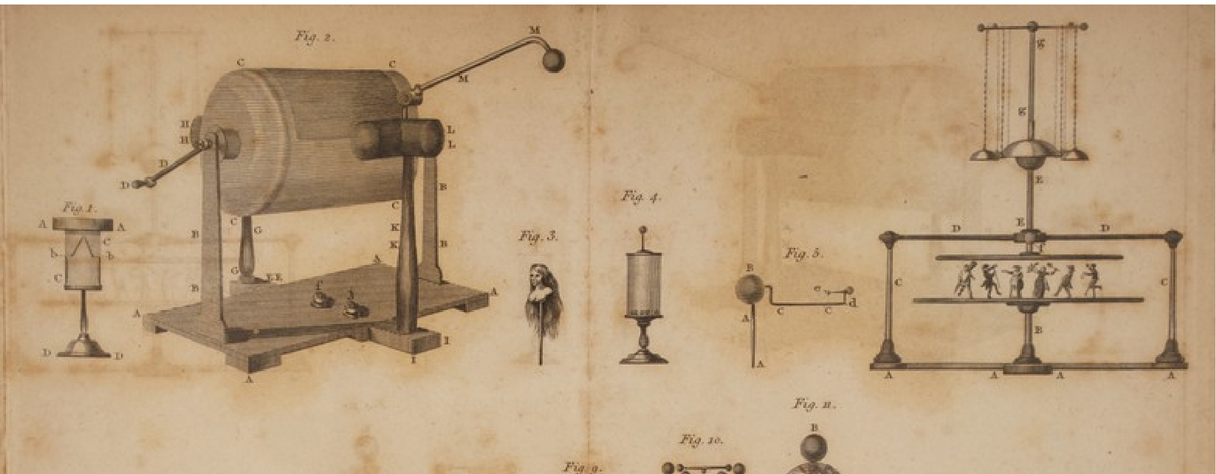


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 11.*
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.
Fig. 18.
White sculp.

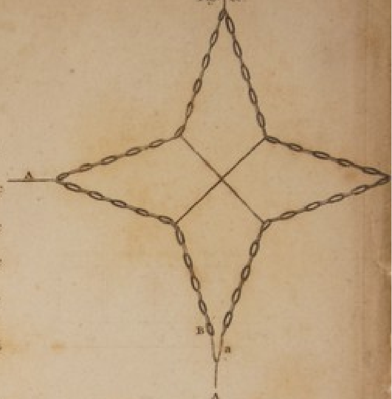
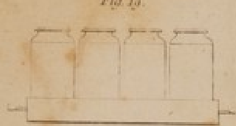


Fig. 22.

Fig. 21.

Fig. 19.



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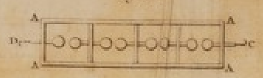


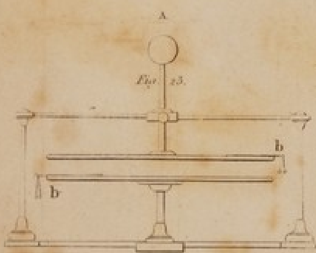
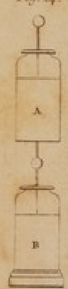


Fig. 23.

Fig. 24.



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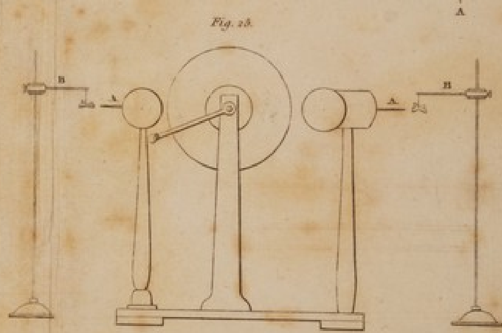

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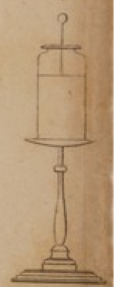

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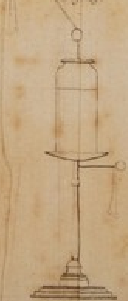

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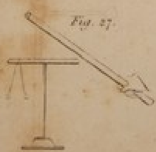

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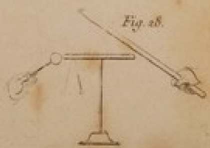

Fig. 30.

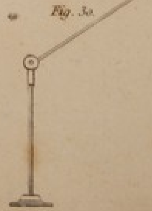

Fig. 31.