MS DESCRIPTIONS
OF EXPERIMENTS
AND PLATES

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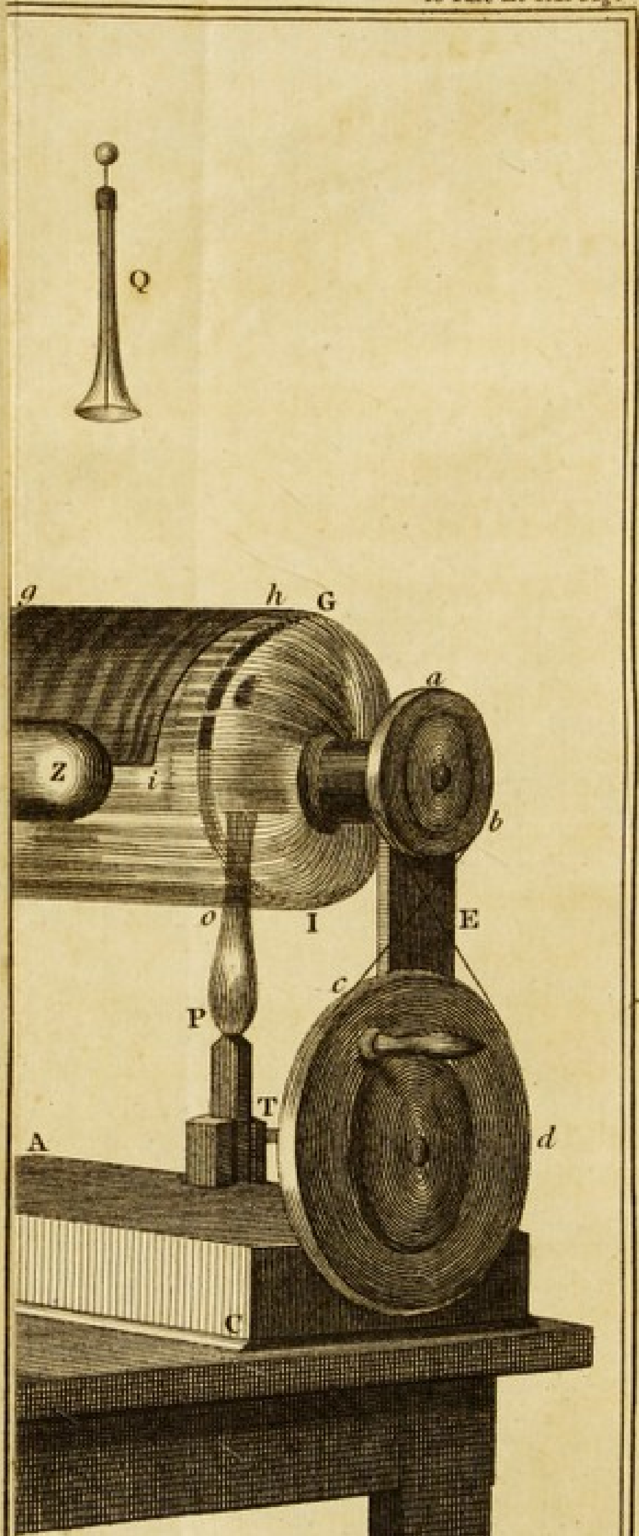

Jas. Lodge sculp.

May 1st 1799.

AS DESCRIPTIONS
OF EXPERIMENTS
AND PLATES

No 17

AN

ESSAY

ON

ELECTRICITY,

EXPLAINING THE

PRINCIPLES OF THAT USEFUL SCIENCE;

AND DESCRIBING

THE INSTRUMENTS,

CONTRIVED EITHER TO ILLUSTRATE THE THEORY, OR RENDER THE PRACTICE ENTERTAINING.

ILLUSTRATED WITH SIX PLATES.

TO WHICH IS ADDED,

A LETTER TO THE AUTHOR, FROM MR. JOHN BIRCH, SURGEON, ON THE SUBJECT OF MEDICAL ELECTRICITY.

BY THE LATE

GEORGE ADAMS,

MATHEMATICAL INSTRUMENT MAKER TO HIS MAJESTY, &c.

THE FIFTH EDITION,

WITH CORRECTIONS AND ADDITIONS, BY

WILLIAM JONES,

MATHEMATICAL INSTRUMENT MAKER.

LONDON:

PRINTED BY J. DILLON, AND CO.

FOR, AND SOLD BY, W. AND S. JONES, OPTICIANS, HOLBORN.

1799.

Price 8s. in Boards.

PREFACE.

It may be easily perceived by the title of this work, that it is not offered to the public as a finished piece on the subject. To treat of the theory and practice of electricity in the fullest manner, would require a larger treatise, and employ more time than I can devote to a work of this kind.

The science of electricity is now generally acknowledged to be useful and important; and there is great reason to think, that at a future period it will be looked up to, as the source from whence the principles and properties of natural philosophy must be derived. Its utility to man will not be inferior to its dignity as a science.

I have not attempted to trace electricity from its first rude beginnings, or to follow the mind of man in its various and irregular wanderings, in search of the laws by which it acts and the source from whence it is derived, as this has been so well executed by Dr. *Priestley*. Our view of things is so circumscribed, and the mysteries of nature so profound, that it is not easy for us to determine, whether the received theory is founded on the basis of truth and conformable to nature, or whether we shall be considered by future philosophers as mere children, amused and satisfied with imperfect opinions and ill-digested theories. When a variety of things are mixed together, which have little or no connexion, they naturally create confusion. It has been my endeavour in the following Essay to collect and arrange in a methodical and concise manner the essential parts of electricity, by these means to render its application easy, pleasant, and obvious to the young practitioner; and, by bringing together experiments of the same kind, make them mutually illustrate each other, and thus point out the strength or discover the weakness of the theories that have been deduced from them. Though the nature and confined limits of my plan did not admit of much variety of observation, or a formal enumeration of every particular, yet few things, I hope, of use and importance have been omitted.

As I do not wish to incur the imputation of plagiarism, I with pleasure acknowledge the assistance I have received from the different authors who have written on this subject. I have used an unreserved freedom in selecting from their works whatever I found to answer my purpose.

The various interruptions and avocations, from which, as a tradesman, I cannot be exempt, will, I hope, induce the reader to make some favourable allowances for any errors which he may discover, and kindly correct them for himself.

Being encouraged by the very rapid sale of the former editions of this work, to offer another to the public, I have endeavoured to render it more perfect by such additions and alterations as either occurred to my own mind, or were suggested to me by others. The reader will find most of the chapters either enlarged by the addition of new matter, or improved by a different arrangement of the old; more particularly, the chapters on medical electricity and the Leyden jar.

ADVERTISEMENT,

BY

THE EDITOR.

THE Editor thinks it proper to acquaint the Reader, that in his revision of this work, he has been careful to correct the referential and other errors contained in it; of the former of which he found too many instances. He has given more explicit descriptions of such apparatus as were either imperfectly explained, or not properly referred to by the late Author. Several additional figures have been inserted in the plates; and, by way of text and occasional notes, some new and useful articles have been printed, unnoticed in the preceding impression; an Index has also been annexed. In the Addenda, a short account is given of the remarkable discoveries and experiments on animal electricity. The considerable number of experiments described in this work has been, perhaps, its chief recommendation; and the Editor conceives it proper to advise any beginner in the science, not at first provided with an electrical machine and apparatus, to furnish himself with a glass tube, a stick of sealing-wax, and a pair or two of pith balls fixed to linen threads for suspension on glass stands, in order to exemplify the fundamental and general properties of the science. The Editor hopes that the corrections and augmentations made to this Fifth Edition, will again render the work deserving of the favourable reception it has hitherto met with.

HOLBORN,
May 1, 1799.

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Holborn,
May 1, 1799.

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AN

ESSAY

ON

ELECTRICITY.

CHAP. I.

CONTAINING A SUMMARY VIEW OF THE GENERAL PRINCIPLES OF ELECTRICITY, OR A SERIES OF INTRODUCTORY PROPOSITIONS AND EXPERIMENTS.

OF ELECTRICITY, OR ELECTRICS AND NON-ELECTRICS.

THERE is a natural agent or power, generally called the *electric fluid*, which by friction, or other means, is excited or brought into action.

This action is manifest to our senses by what are termed electric appearances.

These appearances are; the attraction and repulsion of light bodies; pencils of light darting from the electrified body, attended with a snapping noise, and sometimes fiery sparks, on the approach of certain substances.

Experiment i. Take a dry glass tube, of about an inch and an half in diameter, and about three feet long; rub this tube from one end to the other with the hand, or a piece of dry warm silk, and it will exhibit electric appearances, or be excited. The power thus brought into action will attract and then repel small light bodies, such as a feather, threads, &c. Small pencils of light will also dart from the tube in a beautiful manner, attended with a crackling noise, if the finger, or any metallic substance, is brought near the tube. In a darkened room this experiment will appear to more advantage.

Experiment ii. Put your glass cylinder of the electrical machine in good order, by the rules laid down in Chap. iii.* Then turn the cylinder, and all the forementioned appearances may be observed; but, as the action of the cylinder is stronger than that of the tube, the effects will be

* *Plate* 1, *Fig.* 8, represents a cylinder electrical machine and prime conductor. G H, the glass cylinder; O P, the glass insulating pillar to the rubber and silk, g, h, above; and Y Z, the conductor with its collecting points, supported by a glass pillar. Edit.

more visible in the former. In these two experiments, the friction of the rubber against the tube or cylinder will bring into action, and render sensible an agent of a curious and surprizing nature, which before was apparently dormant and invisible to us.

With respect to the electric matter, all substances are by electricians divided into two classes, *electrics* or *non-electrics*.

Electrics do not suffer the electric matter to pass readily over their surfaces; hence they are also called *non-conductors*.

Non-electrics permit the electric matter to pass readily over their surfaces; from whence they are termed *conductors*.

Experiment iii. A metallic cylinder being fixed upon a glass support, and placed near the electric machine, will receive the electric fluid from the glass cylinder, which will diffuse itself over the whole surface of the metallic cylinder. It does not, however, readily pass over the glass support, but is detained by it on the metallic cylinder, from whence it may be conveyed by any metallic substance.

A metallic cylinder supported by glass, and furnished with sharp-pointed wires to collect the electricity from the glass cylinder, is called the *prime conductor*. It is said to be *insulated* by the glass support, because this obstructs the passage, or cuts off the communication of the electric fluid with the earth. All conducting substances supported on pillars of glass, or other electric substance, are therefore in a state of *insulation*.

This experiment will serve to give a general idea of the foundation of the division of all substances into electrics and non-electrics; but, as it is a distinction which runs through the whole business of electricity, we shall endeavour to elucidate it further, by entering more fully into the properties by which these substances are distinguished.

Electrics, or non-conductors, may have any part of their surface rendered electrical by friction, without diffusing the same kind of electricity to any other part of their substance.

Non-electrics, or conductors, cannot be rendered electrical by friction; and, when electrified by any other means, the electricity is diffused over the whole of their surface, and every part thereof exhibits the same kind of electricity.

The partial distribution of the electric fluid on non-conductors is easily shewn, by only exciting one part of a glass plane, or a glass tube.

The equal diffusion of this fluid is seen by the prime conductor when electrified.

A conductor electrified by communication, parts with the whole of its electricity at once to any conducting substance, (that communicates with the earth,) when brought in contact with it;

or a conductor cannot be electrified while it communicates with the earth, because all the electricity is carried off by the communication. Whereas under the same circumstances an excited electric loses its electricity only in those parts which are near the conducting substance, or to which it is applied.

Experiment iv. To illustrate this position, bring any conducting substance that communicates with the earth in contact with the prime conductor, and it will immediately deprive it of all the electricity it had acquired; but, if the same conducting substance is brought near the excited glass cylinder, it will only take off a portion of the electric matter from that part to which it is applied.

Some conducting substances are more perfect than others.

Experiment v. The electric fluid will pass more readily over a metal rod, than one of wood.

Among conductors, metals are the most perfect; sealing-wax, rosin, and glass, are amongst the best non-conductors. A list of conducting substances will be hereafter given.

The electric fluid may be excited by friction, by heating and cooling.

Experiment vi. In working the electrical machine, this fluid is excited by friction. The

Tourmalin stone is excited by increasing or diminishing its heat.

OF EXCITATION, AND OF THE CONTRARY STATES OF THE ELECTRIC FLUID.

The excitation produced by rubbing of electrics against each other, is very small.

EXPERIMENT VII. Rub two pieces of glass or sealing-wax together, and only a small degree of electricity will be obtained.

It is, therefore, necessary that the rubber should be a conducting substance, and that it should not be insulated.

Only a small quantity of electricity can be produced, when the rubber and conductor of an electrical machine are both insulated.

EXPERIMENT VIII. Take off the chain, which is generally suspended from the cushion of the rubber of a machine; turn the cylinder, and you will find less electricity than when the cushion or rubber communicated, by the chain, with the earth.

If the rubber of an electrical machine be insulated, and the conductor uninsulated, or made to communicate with the earth, by hanging a chain from it; on turning the cylinder, the rubber will be strongly electrified, and will attract and repel light bodies, and exhibit the same general appearances as the prime conductor.

Experiment ix. Connect an insulated conductor with the rubber, place another before the cylinder, and both will be electrified.

The conductor, which is electrified by the cylinder, will attract those bodies which are repelled by the conductor that is connected with the cushion, and *vice versa.*

If these conductors are brought near each other, strong sparks will pass between them.

If they be brought into contact, or if they are connected together by a chain, the electricity of one will destroy that of the other; aud though the fluid may be seen to circulate round the cylinder, yet the two conductors, when thus conjoined, will exhibit few or no signs of electricity.

From these experiments it may be inferred, that there are two powers in electricity, the one termed *positive electricity*, the other *negative electricity*; that these powers may be rendered evident to the senses when they are separated; and that they counteract each other when united, the one destroying the effects of the other.

To render this position more clear, we shall reconsider the foregoing experiments on the two conductors, comparing them with similar experiments on two conductors electrified with the same power. Electrify two conductors equally, by placing them before the cylinder, that is, electrify both positively, and the following observations may be made: 1. That what is attracted or repelled by the one, is also attracted and repelled by the other; whereas, in the foregoing instance, what the one attracted, the other repelled. 2. That no sparks will pass between two conductors equally electrified with the same power, though they will pass continually between two electrified with different powers. 3. Connect the two conductors that are before the cylinder, and sparks may be taken from them, which cannot be done from the others when they are united.

The conductor connected with the cushion is said to be negatively electrified.

The conductor placed before the glass cylinder is said to be positively electrified.*

These experiments, if the rubber be insulated, may be easily exhibited by one conductor, by means of the two directors with glass handles,

* Hence every electrical machine, with an insulated rubber, may be considered as acting in a three-fold manner.

1. As a machine producing *negative electricity*; by connecting the prime conductor to the earth by a chain, and taking the fluid from the cushion or rubber.

2. As a machine producing *positive electricity*. To effect this, make the rubber communicate with the ground by a chain, and take the fluid from the conductor.

3. As communicating the action of *both powers at once*. In this case, the rubber and conductor must both be insulated, and the substance to be electrified placed between two directors connected with them.

that are described in the chapter on medical electricity. Take off the chain from the cushion, and connect a director with it by a wire or chain, and connect another director with the prime conductor; turn the cylinder, and on bringing the directors near to each other, sparks will pass from the one to the other; the one will also attract what the other repels, and, when brought into contact, neither of them will exhibit any signs of electricity.

The electricity produced by the excitation of glass is called positive electricity, by some writers *vitreous*.

The electricity produced by the excitation of sealing-wax, or rosin, is called negative, and by some writers *resinous*.

OF ELECTRICAL ATTRACTION AND REPULSION.

If two bodies be electrified, both positively or both negatively, they repel each other.

If one be electrified positively, the other negatively, they attract each other.

A body not at all electrified will be attracted by those which are electrified, either negatively or positively.

EXPERIMENT X. Electrify a pair of insulated pith balls positively, and they will repel each other.

EXPERIMENT XI. Electrify a pair of insulated pith balls negatively, and they will repel each other. See *plate* 2, *fig*. 24, 25, 26, 27.

EXPERIMENT XII. A pair of insulated pith balls electrified positively, will attract a pair that are electrified negatively.

EXPERIMENT XIII. A pair of insulated pith balls, electrified negatively, are attracted by excited glass, and repelled by excited wax; and the contrary: for, if the balls are electrified positively, they will be repelled by excited glass, and attracted by excited wax.

EXPERIMENT XIV. A pair of insulated balls, in their natural state, are attracted both by excited glass and excited wax.

The repulsion of balls electrified positively is destroyed by the application of an equal degree of negative electricity.

EXPERIMENT XV. Electrify two pair of insulated pith balls equally, but one with positive electricity, the other with negative; bring the cylinders, by which the balls are suspended, in contact, and the balls will immediately close.

EXPERIMENT XVI. Electrify two pair of insulated pith balls equally with positive electricity, bring the cylinders by which they are suspended in contact, the balls will remain unaltered.

From these experiments it may be inferred, that in the natural state of electricity the two powers are always united; that they only become visible by their separation, and that when separated, they manifest themselves by those appearances which we term electrical. It is highly probable, that the general phenomena of nature are carried on by these powers when united, and the more particular phenomena, or discordant notes in the great system of the universe, are occasioned by the action of these powers when separated, and their constant tendency to unite. Be this as it may, the foregoing positions will be found to illustrate all the experiments on electric attraction, from which we have selected the following, as some of the most pleasing.

Experiment xvii. Light feathers, hair, &c. connected with the conductor, are, when electrified, attracted by any non-electric body.

Experiment xviii. The hair of any person that is electrified becomes repellent.

Experiment xix. Downy feathers, small pieces of leaf gold, paper images, and other light bodies, brought near the conductor, are first attracted and then repelled.

Experiment xx. The two outside bells, *plate* 2, *fig.* 17, communicate by a chain with the conductor; the middle bell and the two clappers are suspended by silken strings, which are non-conductors. The electric fluid passes from the conductor to the outside bells, these attract the clappers and impart electricity to them, which they in their turn communicate to the middle bell, from whence it is conveyed by a brass chain, X, to the earth. The clappers, in receiving and communicating the fluid, are alternately attracted and repelled.

Those substances that are brought within the influence of electrified bodies, become possessed of a contrary electricity; or, bodies which are immerged in an electric atmosphere always become possessed of an electricity contrary to that of the body in whose atmosphere they are immerged.

Experiment xxi. Bring a conductor without pointed wires near to the glass cylinder, whilst the machine is working. If the conductor be not insulated, it will be negatively electrified, till it is brought so near as to receive sparks from the cylinder. If the conductor be insulated, it will in the same situation be electrified negatively, in the parts nearest the glass cylinder, and positively, in the parts more remote; as may be seen by bringing a glass tube, which is positively electrified, near a ball which is suspended from the conductor.

OF ELECTRIFIED POINTS.

The electric fluid appears as a diverging stream darting forwards into the air from a pointed body positively electrified. It appears as a little globular star on a point negatively electrified.

Experiment xxii. These appearances are to be observed in a dark room on the extremity of a pointed wire, fixed upon a conductor positively or negatively electrified; or on a wire held in the hand, and presented to a positively or negatively electrified conductor.

Experiment xxiii. These phenomena are beautifully exhibited by the luminous conductor, *plate* 4, *fig*. 61 and 62.

A current of air is occasioned from an electrified point.

Experiment xxiv. Place a pointed wire in the conductor, and hold the hand over it when the machine is in action, a very sensible wind will be felt by the hand.

Experiment xxv. Stick several pieces of paper or card like vanes in a cork, through the center of which a needle or steel pin passes; suspend the whole by a magnet; present one of the vanes to a pointed wire inserted in the conductor, and they will be put in motion by the current occasioned by the point, and will turn with rapidity.

A pointed wire placed on, or brought near to an electrified conductor, gradually and silently dissipates the electric fluid.

It is to be observed here, that if the point be brought within certain limits, it will not discharge the conductor in the manner expressed in the foregoing position, but by a succession of small explosions very quickly following each other, which leads to the following position.

If an electrified point be situated in such circumstances as to cause the fluid to accumulate on the conductor; or, in other words, if it be so situated, that the power of the same name with that of the conductor cannot be readily discharged from it, it will then receive the electricity from the conductor in the form of a strong spark.

Experiment xxvi. Place a pointed wire on the end of a spiral tube, *plate* 3, *fig.* 31, and it will take a spark.

OF THE LEYDEN PHIAL.

A glass jar or phial coated on both sides, except about two inches from the top, with tin-foil, or any other conducting substance, is called the Leyden jar or phial. See *plate* 3, *fig.* 42.

If one side of this jar is electrified, while the other side communicates with the earth, it is said to be charged.

If a communication is formed from one side of the jar to the other, by a conducting substance, after it has been charged, an explosion will be heard, and the jar is said to be discharged.

A Leyden phial cannot be charged when it is insulated; that is, when neither side communicates with the earth.

As the apparatus represented at *plate* 2, *fig*. 49, is the most ready, and best adapted for illustrating the phenomena of the Leyden phial, we shall confine ourselves principally to it in this part of the present Summary.

EXPERIMENT XXVII. Screw the phial with the belt on its insulated stand, as at F, *plate* 3, *fig*. 48; bring the coating in contact with the conductor, turn the machine slowly, and, after a few turns, remove the phial from the conductor; then form a communication between the outside and the inside of the phial, by placing one end of the discharging rod first upon the coating, and then bringing the other end of the rod to the brass ball of the bottle; there will be no explosion, the bottle not being charged, because both sides were insulated.

EXPERIMENT XXVIII. Hang a chain from the brass ball of the phial to the table, then bring the coating in contact with the conductor, and, after a few turns of the machine, remove the phial as before; then apply the discharger, an explosion will be heard, and the bottle will be discharged; for, in this case, the insulation of the inside is destroyed by the chain, and the phial becomes capable of receiving a charge.

As much of the electrical fluid is thrown off from one side of a jar when charging, as is communicated to the other.

EXPERIMENT XXIX. Place the coating of the jar, *plate* 3, *fig*. 48, in contact with the conductor, and the knob of another equal sized jar, as I, *fig*. 49, in contact with the knob of the first; turn the machine a few times, then remove the jars from each other, and from the conductor; apply a discharger, as before directed, first to the one, then to the other, and you will find them both equally charged; the inside of the second phial having received from the inside of the first as much of the fluid as the outside thereof received from the machine.

When a Leyden phial is charged, the two sides thereof are in contrary states; that is, the one is positively, the other negatively electrified.

EXPERIMENT XXX. Charge the jar, *fig*. 48, by bringing the coating in contact with the conductor, and letting a chain fall from the ball to the table. When it is charged, remove the jar from the conductor, and the chain from the knob. The coating of the jar will electrify a pair of insulated pith balls positively, and the knob will electrify a pair negatively; evincing that the inside and outside of the jar are in contrary states.

Reverse the foregoing experiment, by bringing the knob of the jar in contact with the conductor, and letting a chain fall from the outside coating to the table; charge the jar, and remove the chain, the coating will now electrify the insulated pith balls negatively, and the knob will electrify them positively.

Experiment xxxi. Charge the jar, *plate* 3, *fig.* 48, positively; connect a director with the chain from the coating, and bring the ball of the director towards the knob of the jar; a cork ball or an artificial spider, suspended by a silk string, will play between the two balls till the bottle is discharged, carrying the fluid from one to the other, till it has restored the equilibrium.

A jar is said to be positively electrified, when the inside receives the fluid from the conductor, and the outside is connected with the earth.

It is said to be negatively electrified, when the outside receives the fluid from the conductor, and the inside communicates with the earth.

It is necessary that a jar charging negatively should be insulated, because the fluid is, in the first instance, conveyed to the coating, and would, if uninsulated, be immediately carried to the earth.

The contrary states of the Leyden phial may be shewn by the charge and discharge thereof.

Experiment xxxii. Take two jars of the same size, as H and I, *plate* 3, *fig.* 49; charge both positively, and connect the coatings of each, as in *fig.* 43; bring the two knobs together, and no explosion will take place, and the jars will not be discharged; because the inside and outside of each jar is in the same state, or endued with a power of the same kind, and have therefore no tendency to unite. The same happens if both are charged negatively.

EXPERIMENT XXXIII. Charge one jar positively, the other negatively; then, on bringing the knobs together, as before, an explosion will take place, and both jars will be discharged; in this the powers on the inside and outside of each jar were of different kinds, with a strong tendency to unite.

In the foregoing experiments it will be found very convenient for the discharge of the jars, to screw the wires, K or L, *fig.* 49, into the hole at the top of the insulating pillar; as the coating of the moveable jar may be placed on this wire, and its knob be easily brought to touch the insulated jar.

The contrary states of the sides of a Leyden phial may be exhibited by the appearance of the electric light, or pointed wires connected with the coating or balls of the bottle; and also by the different appearance thereof in vacuo. But for these we shall refer the reader to the following Essay, as the foregoing experiments are sufficient to prove the fact.

The charge of a coated jar resides in the glass, and not in the coating.

EXPERIMENT XXXIV. Let a plate of glass be placed between two metallic plates, about two inches in diameter, smaller than the plate of glass; charge the plate of glass, and then remove the upper metallic plate by an insulated handle; take up the glass plate, and place it between two other plates of metal unelectrified and insulated, and the plate of glass thus coated afresh will yet be charged.

The passing of the electric fluid from one side of a charged jar to the other, is apparently instantaneous, through whatever length of a metallic or other good conductor it is conveyed.

Experiment xxxv. Let any number of persons make a part of the circuit of communication, and the fluid will pass instantaneously through the whole.

The discharge of a charged jar gives a painful sensation, called the electric shock, to any animal, or its part, placed in the circuit of communication.

If the circuit be interrupted, the fluid will become visible; and if resisted in its passage, will leave an impression upon the intermediate or resisting bodies.*

Experiment xxxvi. Let the fluid pass through a chain, or through any metallic bodies placed at small distances from each other; the fluid, in a darkened room, will be visible between the links of the chain, or between the metallic bodies.

* *Enfield's* Institutes of Natural Philosophy.

EXPERIMENT XXXVII. If the circuit be interrupted by several folds of paper, a perforation will be made through it, and each of the leaves will be protruded by the stroke from the middle towards the outward leaves.

EXPERIMENT XXXVIII. If spirit of wine or gunpowder be made part of the circuit, it will be fired.

The force of an electric charge does not depend on the shape of the charged surface.

Let the same quantity of coating be placed upon a jar and upon a plate of glass, the effect will be found to be nearly the same in each.

When the surfaces of an electric jar are charged with a certain quantity of the two powers, it is observed that no additional electricity can be communicated to them, however great an excitation is applied for that purpose.

OF THE ELECTRIC BATTERY.

The force of the electric charge may be increased, by augmenting the surface of coated glass.

The usual method of effecting this, is to form a communication between the insides of a number of coated glass jars, and another communication between the external coatings: jars so disposed are called an electrical battery. See *plate* 4, *fig.* 65.

Fine metallic wire may be melted by a battery, small animals may be killed, thick pieces of glass be shattered to pieces, and other curious effects produced, the greater part of which are described in the course of this Essay.

The electric fluid and lightning are the same substance.

Their properties and effects are the same; flashes of lightning form irregular lines in the air; the electric spark, when strong, has the same appearance. Lightning strikes the highest and most pointed objects, takes in its course the best conductors, sets fire to bodies, melts metals; in which, and many other particulars, it agrees with the phenomena of the electric fluid. Lastly, the lightning being brought from the clouds to an electrical apparatus, will exhibit all the appearance of the electric fluid.

It is supposed that buildings may be secured from the effects of lightning, by fixing a pointed metallic rod higher than any part of the building, and continuing it without interruption to the ground or nearest water.

The experiment most generally used to illustrate this position, is that of the thunder-house, which is a board shaped like the gable end of a house, and fixed perpendicularly upon an horizontal board; in the perpendicular board a square hole is made, into which a square piece of wood is to be fitted, so that it may easily fall out of its place; a wire is fixed diagonally into this square piece; another wire, terminated with a brass ball, is fastened to the upper part of the perpendicular board, with its ball above the board, and its lower end in contact with the diagonal wire; in the square piece of wood, a communication is continued from the other end of the diagonal wire, by a wire to the bottom of the perpendicular board. If the wires in this state are made part of a circuit of communication, on discharging the jar, the square piece of wood will not be displaced; but, if the communication be interrupted by changing the direction of the diagonal wire, the square piece of wood will, on the discharge, be driven out of its place. See *fig.* 68.

If, instead of the upper brass ball, a pointed wire be placed above the perpendicular board, the discharge may be drawn off without an explosion.

OF A PLATE OF AIR.

As the air is an electric, it will receive a charge and give a shock, like any other electric substance.

This is effected by means of two large boards, covered with tin-foil, the one connected with the conductor, the other placed parallel to it on an insulated stand; these boards may be considered as the coatings to a plate of air; and, if a communication be formed between them, by touching the uninsulated board with one hand, and applying the other hand to the conductor, the shock will be felt. See *Nicholson's* Introduction to Natural Philosophy.

" A great part of the electric phenomena are the consequence of the air being thus charged. Thus, the prime conductor imparts its electricity to the surface of air immediately contiguous to it, and when the spark is drawn, the discharge is made to the non-electrics in the room, which are in contact with the opposite surface.

" It is a consequence of the air being charged, that broad non-electric surfaces draw large sparks from the conductor; for the sparks are the discharges of a large plate of interposed air: a less surface will draw a less spark, because the same machine discharges less surfaces higher than greater; the spontaneous discharge through the body of the electric air will be made at a greater distance of the surfaces; that is to say, the sparks will be longer. If the surface of the presented plate be still smaller, the sparks will also be smaller, and emitted to a greater distance; and if the surface be indefinitely small, or in other words, if the non-electric be pointed, the spark may be so small as to be invisible, and the distance to which it can be emitted, may be unlimited."

OF MEDICAL ELECTRICITY.

The satisfactory experiments that have been made on this head, by some of the first characters in the medical line, particularly at St. Thomas's Hospital, by Mr. *Birch*, have established the reputation of electricity in medicine; as they have clearly proved, that when used by the skilful, it is as certain in its effects as any medicine in the whole materia medica, and more extensive in its application.

In medicine, it has been very judiciously considered as acting under three forms:

1. *The fluid*, which may be considered as a sedative.

2. *The spark*, or friction, which may be ranked under the title of a stimulant.

3. *The shock*, which may be considered as a powerful deobstruent.

The fluid may be thrown upon, or extracted from the patient.

This is always best affected by a wooden point.

1. Insulate the patient, and connect him with the positive conductor; then present the wooden point of the director towards him, and it will gradually draw the fluid from him.

2. Let the patient communicate with the ground, and connect the metal part of the director with

the positive conductor, and the fluid will be gently thrown upon the patient.

3. Connect the insulated patient with the cushion, then he will receive the fluid from the director held in the hand.

4. Connect the director with the cushion, and the fluid will be extracted from the patient.

OF THE ELECTRIC SPARK, OR FRICTION.

What has been said with respect to the fluid, is equally applicable to the electric friction; only here the point is to be unscrewed from the director, and the brass ball screwed on in its stead.

In the friction, the part should be covered with woolen cloth or flannel, and the brass ball is to be applied close to the flannel; but, in taking sparks, it is to be removed a little distance from the body.

TO INCREASE THE DENSITY OF THE FLUID, OR SPARK.

Fix the medical bottle to the conductor; let a chain fall from the hook at the bottom thereof to the table; place the electrometer on the conductor, as it is represented in the frontispiece to this work; let the ball of the electrometer be placed at some little distance from the conductor, and then connect your director, by means of a wire, with the exterior ball of the electrometer. After this preparation, you may turn the machine, and when the fluid has attained sufficient force to pass from the conductor to the ball of the electrometer, you may apply the director to the patient, who will receive a dense stream therefrom: the machine to be kept turning during the operation. Or, connect an insulated patient with the electrometer, and then, on applying the director to him, you will extract a dense stream from him.*

N. B. Whenever the director is used without being connected with the conductor or cushion, the hand should communicate with the brass part thereof.

TO PASS A STREAM OF THE ELECTRIC FLUID THROUGH ANY PART OF THE BODY, WITHOUT GIVING THE SHOCK.

1. Connect one director with the cushion, and another with the conductor; place the part, through which you want the stream to pass, between the directors.

N. B. The density of this stream is augmented, if the bottle is suspended agreeable to the directions in the preceding article, and one director joined to the electrometer.

* I have given a particular description of this medical apparatus in Chap. iii. EDIT.

2. Insulate the patient, and apply a director that communicates with the conductor, or with the electrometer and bottle, to one part, and a brass ball to the other.

TO GIVE THE SHOCK.

Suspend the bottle from the conductor, put the electrometer in its place, (see the plate that faces the title-page of this work, (and remove the inner ball a small distance from the conductor; then connect one director by a wire with the hook at the bottom of the bottle, and the other with the exterior ball of the electrometer; the part through which the shock is to pass, must be placed between these balls; there will be a shock every time the fluid has acquired sufficient force to pass from the conductor to the electrometer.

TO GIVE A QUICK VIBRATORY SENSATION, NOT SO PUNGENT AS THE SHOCK, THOUGH STRONGER THAN THE SPARK.

The directions in the preceding article apply immediately to the present, with only this difference, the ball of the electrometer may be removed further off, and the long wire is to be taken out of the tube of the bottle.

OF ATMOSPHERIC ELECTRICITY.

The atmosphere is always electrified, sometimes negatively, but most commonly with positive electricity. In serene weather the electricity is always positive, and the quantity is proportional to the quantity of moisture.

Hail is always accompanied with electricity.

Rain generally so.

Low and thick fogs strongly electrical, though generally more so after a frost.

In summer, the electricity of the atmosphere is very weak, it grows stronger at sun-rise, and increases in strength with the elevation thereof; at sun-set it again becomes weaker.

Impetuous winds generally lessen the force of the atmospheric electricity.

A strong electricity often rises with the dew, particularly if the season is cold, the sky clear, and very little wind.*

* The following are the most approved atmospherical electrometers, and are described in Chap. xviii. the first is considered the most sensible. *Plate* 1, *fig*. 10, Bennet's gold leaf electrometer; *fig*. 11, Cavallo's pith ball electrometer, improved by Saussure; *plate* 4, *fig*. 76, Cavallo's pith ball electrometer.

EDIT.

OF A VACUUM.

Air rarefied to a certain degree, permits the electric fluid to pass easily through it.

As the air is a non-conductor, it resists the motion of the electric fluid; therefore, the removal of it facilitates the effort this fluid makes to escape from the subject on which it is thrown; at the same time it is highly probable, that it is by means of the vapour, which expands itself when the pressure of the atmosphere is taken off, that the electric fluid is conducted through the vacuum; for there is reason to think, that electricity always requires a conductor, to make it pass from one body to another; and this is further confirmed by those experiments which shew that a more perfect vacuum of air is a non-conductor.

Experiment xxxix. Let a vacuum be made part of the circuit in discharging a Leyden phial.

Experiment xl. Let a jar be charged in vacuo.

CHAP. II.

OF ELECTRICITY IN GENERAL—OF THE DISTINCTION BETWEEN ELECTRICS AND NON-ELECTRICS—A CATALOGUE OF CONDUCTING SUBSTANCES—OF THE ANALOGY BETWEEN ELECTRICITY AND FIRE.

It must appear surprizing to every searcher after truth, that electricity, which is now allowed to be one of the principal agents employed in producing the phenomena of nature, should have remained so long in obscurity; for, comparatively speaking, its existence was not known to the ancients. They were not, indeed, altogether ignorant of the peculiar properties of those bodies that we now term electrics; nevertheless their knowledge was circumscribed, being confined to the observation only of those phenomena which nature presented to their senses, in the ordinary course of her operations; hence near two thousand years elapsed, before any addition was made to the little which was known to *Theophrastus*, and this branch of natural history remained uncultivated, till the happy period arrived, when the philosopher was emancipated from the chains of hypothetic reasoning, and the uncertainties of vague conjecture.

The existence of this subtile, and in most cases invisible power, was then traced, and many of its properties developed; its agency was discovered to be universal, and its extent unlimited.

It must be evident, indeed, even to a superficial observer, that electricity is no trivial or confined subject; because there is no body in nature that is not acted upon in a greater or less degree by this important agent.

The importance of the electric fluid in the system of the world is confirmed by a consideration of those phenomena in which it is concerned, and which take place without the concurrent operation of man.

Thus, several fishes possess the property of giving the electric shock. The torpedo, and one or more species of eels, from Surinam, if touched by the hand, a metal rod, or any other conductor, give a considerable shock to the arm, but may be safely touched by a piece of sealing-wax. The shock depends on the will of the fish, and is transmitted to a great distance; so that if persons in a ship happen to dip their fingers or feet in the sea, where the fish is swimming at the distance of fifteen feet, they will be affected therewith.

Many disorders of the human frame have been cured or relieved by electricity; new action has been given to deficient powers, and the terrors of the knife been frequently prevented.

But the most remarkable appearances of electricity, which are viewed with surprize by all ranks of people, are those which may be termed atmospherical, as existing in, or depending on the state of the atmosphere. Lightning is proved to be an electric phenomenon, and there is little doubt but that the aurora borealis, whirlwinds, and water-spouts, depend on the same principle.

"Electricity has one considerable advantage over most other branches of science; it furnishes matter of entertainment for all persons promiscuously, while it is a subject for speculation to philosophers. Neither the air-pump, nor the orrery; neither experiments in hydrostatics, optics, or magnetism; nor those in all other branches of natural philosophy, ever brought together so many or such great concourses of people, as those of electricity have done singly."

"If we only consider what it is in objects that makes them capable of exciting that pleasing astonishment, which has such charms for all mankind, we shall not wonder at the eagerness with which persons of both sexes, and of every age and condition, run to see electrical experiments. Here we see the course of nature to all appearance entirely reversed in its most fundamental laws, and by causes seemingly the slightest imaginable: and not only the greatest effects produced by causes which seem to be inconsiderable, but by those with which they seem to have no connexion."

Here we see, contrary to the principles of gravitation, bodies attracted, repelled, and held suspended by others, which are seen to have acquired that power by nothing but a very slight friction! Here we see a piece of cold metal, or even water or ice, emitting strong sparks of fire, so as to kindle many inflammable substances! Again, what can seem more miraculous, than to find that a common glass jar should, after a little preparation, be capable of giving a person such a violent sensation, as nothing else in nature can give, and of even destroying animal life; and that this shock is attended with an explosion like thunder, and a flash like lightning!

As electricity is in its infancy, when considered as a science, its definitions and axioms cannot be stated with geometric accuracy. I shall endeavour to avoid as much as possible the use of positive expressions, in order to invite the reader to examine the experiments himself, to compare them one with another, and then draw his own conclusions; beginning with those experiments which were the foundation of the present state of electricity, and which gave rise to the principal technical terms made use of in this science.

EXPERIMENT I. Rub a dry glass tube with a piece of dry silk, and it will thereby be electrified; present light bodies, as feathers, pith balls, &c. to it, they will be attracted and then repelled.

A piece of black or oiled silk, on which a little amalgam has been spread, makes the best rubber for a smooth glass tube; soft new flannel succeeds well with sealing-wax.

EXPERIMENT II. Rub a dry stick of sealing-wax, it will first attract and afterwards repel those light bodies that are brought near to it.

The friction in the two preceding experiments has put in action an agent or power, which attracts and repels light bodies; this power is called *electricity*.

A certain quantity or natural share of the electric fluid is supposed to be disseminated in all bodies, in which state it makes no impression on our senses; but when, by the powers of nature or art, this equilibrium is destroyed, and the agency of the fluid is rendered visible to the senses, then those effects are produced which we term *electrical*, and the body is said to be *electrified*.

Any substance that is made by friction to exhibit electric appearances, is said to be *excited*.

Amber, silk, jet, dry wood, and a variety of other substances, being excited, attract and repel light bodies, these are called *electrics*. Such substances, as metals, water, &c. the friction of which will not produce this power of attraction and repulsion, are called *non-electrics*.

When the excited glass tube, or stick of sealing-wax, is in good order, and the particles of electricity are sufficiently united to act on the organs of vision in a darkened room, pencils of light, or flashes of divergent flame will dart from the tube in a beautiful manner, attended with a crackling noise, which will be heard on the approach of any conductor. The matter causing this light and sound is what is meant by electricity.

Electricity is often excited by other causes as well as friction. Thus it may be produced by heating or cooling of some substances, by blowing of air violently on a body, &c. nay, it is probable, that whatever removes the stratum of air from the surface of any body, or influences the cohesion of its parts, will disturb the electric fluid.

The discharge of large cannon, and the blowing up of powder magazines, has been known to electrify glass windows.

EXPERIMENT III. Let a metallic cylinder be placed upon silken lines, or upon glass, bring an excited electric near to it, and every part of the metallic cylinder will attract and repel light bodies as forcibly as the excited electric itself.

EXPERIMENT IV. Support a dry glass rod on silken lines, or by glass, bring an excited electric near it, and no attraction or repulsion will take place, because the electricity cannot be transmitted through it.

From these experiments is deduced the distinction between those bodies which produce the electric fluid, and those which do not; the one having the power of transmitting this fluid, the other possessing no such power.

Those bodies which possess the power of transmitting electricity, are called *conductors* and *non-electrics*.

Those substances which are impervious to electricity, are called *non-conductors* or *electrics*.

A body which communicates with nothing but electrics, is said to be *insulated*.

If all substances possessed an equal power of retaining or parting with the electric fluid, the greater part of its phenomena would have remained unknown to us; but, as it passes readily only over the surface of some substances, while others resist its passage, or are nearly impermeable to it, we are enabled to accumulate, condense, and retain it on the last, and thus subject it easily to the test of experiment.

From the two last experiments we learn, that excited electrics will communicate the electric powers to conducting substances which are insulated; that these will then attract and repel light bodies, &c. similar to the electric itself, with this difference only, that a conductor which has received electricity parts with it at once when it is touched by another conductor that communicates with the earth, whereas the excited electric, under the same circumstances, only loses its electricity partially.

A conductor cannot be electrified while it communicates with the earth, because the electricity is immediately conveyed away.

An insulated electrified conductor will be deprived of its electricity, by taking a spark from any part thereof with an uninsulated conductor.

Experiment v. Electrify with excited glass or sealing-wax two insulated cork balls, suspended by lines about six inches long, and the balls will separate from and repel each other.

Experiment vi. Electrify one ball with glass, the other with sealing-wax, and they will be mutually attracted.

These two opposite and remarkably distinct effects in the attractive and repulsive powers of electricity, whereby one attracts what the other repels, were discovered at an early period of the history of this science.

The electric power produced by the excitation of glass, is called *positive electricity*, and the power produced by the excitation of sealing-wax is called *negative electricity*. This difference was at first thought to depend on the electric, and it was then supposed that the two kinds of electricities were essentially distinct; but it is now known that each of these powers may be produced from the excitation of either glass or sealing-wax.

Electricians have been engaged, by the discovery of the two foregoing distinctions, to examine the electric properties of most bodies, to ascertain whether they possessed the positive or negative powers. By these means the catalogue of electrics has been considerably increased; and it was soon found that every substance we were acquainted with had more or less affinity with the electric fluid.*

CATALOGUE OF CONDUCTING SUBSTANCES.

1. *Stony Substances.*

Stony substances in general conduct very well, though dry and warm.

Lime-stone and lime just burnt are equally imperfect conductors.

Marbles conduct considerably better than free-stone, and there is found very little difference

* See Dr. *Priestley*'s History; *Cavallo* on Electricity; *Marat*, Recherches sur l'Electricite.

among any of the specimens of marble that have been tried.

A large piece of white spar, with a tinge of blue, and semi-transparent, will hardly conduct in the least degree: rather strong sparks may be taken from the prime conductor, while it is in contact with it.

A piece of agate, semi-pellucid, receives the electric spark into its substance, though it will pass over about three-quarters of an inch of its surface to reach the finger that holds it, and it discharges the battery but slowly.

A piece of slate, such as is commonly used to write upon, is a much better conductor than a piece of free stone, which conducts but imperfectly.

Touch-stone conducts tolerably well.

A piece of gypsum and plaster of Paris conducts very well, only the latter having a smoother surface takes a stronger spark.

A piece of asbest from Scotland, just as it is taken from its bed, will not conduct. While in contact with the conductor, sparks may be taken at the distance of half an inch with a moderate electrification.

A piece of Spanish chalk conducts much like marble.

A piece of Egyptian granite conducts considerably better than free-stone.

2. *Saline Bodies.*

Oil of vitriol conducts very well.

The metallic salts in general conduct better than any neutrals.

Vitriol of copper and of iron conduct very well, though they will not transmit a shock.

Vitriolated tartar gives a small shock.

Salt-petre does not conduct so well as sal-ammoniac. If the electric explosion passes over its surface, it disperses into a great number of fragments, in all directions, with considerable violence.

Volatile sal-ammoniac gives a small shock.

Rock-salt conducts, but not quite so well as alum; the electric spark upon it is peculiarly red.

Sal-ammoniac exceeds rock-salt and alum in its conducting powers, but will not take the least sensible spark; so that it seems made up of an infinite number of the finest points.

Salenitic salts conduct but imperfectly.

By alum the explosion is attended with a peculiar hissing noise, like that of a squib.

3. *Inflammable Bodies.*

A piece of pyrites of a black colour takes sparks at a considerable distance from the prime conductor, like some of the inferior pieces of charcoal, Another piece of pyrites, which has been part of a regular sphere, consisting of a shining metallic matter, will not conduct near so well, though much better than any other stony substance. It is a medium betwixt a stone and an ore.

Black-lead in a pencil conducts a shock seemingly like metal or charcoal. A small lump of it takes as full and strong a spark from the prime conductor as a brass knob.

4. *Metals and Ores.*

A piece of gold ore from Mexico is hardly to be distinguished in this respect from the metal itself.

A piece of silver ore from Potosi, though mixed with pyrites, conducts very well.

Two pieces of copper ore, one the most valuable that is known, and another of only half the value, are hardly to be distinguished from one another in their conducting powers.

Lapis hæmatites conducts tolerably well.

Black sand from the coast of Africa, which is a good iron ore, and part of which is affected by the magnet as much as steel filings, is found to conduct electricity, but not a shock. Separating with the magnet all that will be easily attracted by it, it conducts a shock very well: the rest would hardly conduct at all.

The ores in which the metal is mineralized with sulphur or arsenic, as the ores of lead, tin, and cinnabar, the ore of quicksilver, are little inferior to gold and silver ore.

Ores that contain nothing but the earth of the metal, conduct electricity little better than other stones.

Lead, tin, iron, brass, copper, silver, and gold.

5. *Fluids.*

The fluids of an animal body.

All fluids, excepting air and oils.

Fluids appear, in general, to be better conductors in proportion as they contain less inflammable matter.

Mr. *Cavendish* has shewn, that iron wire conducts about four-hundred millions of times better than rain or distilled water; *i. e.* the electricity meets with no more resistance in passing through a piece of iron wire four-hundred million inches long, than through a column of water of the same diameter only one inch long.

Sea water, or a solution of one part of salt in thirty of water, conducts an hundred times, and a saturated solution of sea-salt seven-hundred and twenty times better than rain water.

The effluvia of flaming bodies.

Snow, smoke, the vapour of hot water, the vacuum produced by an air-pump, charcoal, &c.*

* Ice is ranked among conductors, although but an imperfect one. EDIT.

ELECTRIC BODIES.

Amber, jet, pitch, and sulphur; likewise all the precious stones, as diamonds, rubies, garnets, topazes, hyacinths, chrysolites, emeralds, sapphires, amethysts, opals, and especially tourmalins; all resins and resinous compounds, wax, silk, cotton; all dry animal substances, as feathers, wool, hair, paper, &c. White sugar, air, oil, chocolate, calxes of metals, dry vegetables, &c.

I do not know whether it is altogether proper to add to this list of electrics the torpedo and Surinam eel, living electrics, whose electricity is put in action by the will of the animal.

The real and intrinsic difference between electrics and non-electrics remains among the electric desiderata; for nothing more is ascertained, than that the conducting power in some measure depends upon, or is governed by heat. Glass, resin, and many other articles, are made conductors by heat; while, on the contrary, cold, if not attended with moisture, renders every electric substance more electric. Ice cooled to 13° below 0 of Fahrenheit's thermometer becomes a non-conductor.

Mr. *Achard*, of Berlin, has published in *Rozier*'s Journal de Physique, a very ingenious paper on this subject; in which he proves by experiment, 1st. That certain circumstances will cause a body to conduct electricity, which before was a non-conductor. 2d. That these circumstances are the degrees of heat to which the body is subjected. There is certainly reason to suppose, that the disposition in metals to conduct electricity, depends on the state of fire within them, and that there is a certain degree of heat at which a given body may be at the medium between perfect conducting and non-conducting; and that conductors are bodies, whose electric state does not appear but in a degree of cold below the usual state of our atmosphere; and that electrics, to be rendered conductors, require a degree of heat much above the usual state of the air with us.*

A LIST OF ELECTRIC SUBSTANCES, AND OF THE DIFFERENT ELECTRICITIES PRODUCED BY THEM.

The back of a cat	Positive	Every substance with which it has been hitherto tried.
Smooth glass	Positive	Every substance hitherto tried, except the back of a cat.

* This philosopher has found that a rod of ice, two feet long and two inches diameter, was a very imperfect conductor. By constructing a machine with a whirling spheroid of ice, he even electrified a prime conductor, so as to attract, repel, give shocks, &c. EDIT.

Rough glass	Positive	Dry oiled silk, sulphur, metals.
	Negative	Woolen cloth, quills, wood, paper, sealing-wax, white wax, the human hand.
Tourmalin	Positive	Amber, air.*
	Negative	Diamond, human hand.
Hare's skin	Positive	Metals, silk, loadstone, leather, the hand, paper, baked wood.
	Negative	Other fine furs.
White silk	Positive	Black silk, metals, black cloth.
	Negative	Paper, hand, hair, weasel's skin.
Black silk	Positive	Sealing-wax.
	Negative	Hare's, weasel's, and ferret's skins, loadstone, brass, silver, iron, the hand.
Sealing-wax	Positive	Metals.
	Negative	Hare's, weasel's, and ferret's skins, hand, leather, woolen cloth, paper.
Baked wood	Positive	Silk.
	Negative	Flannel.

Many circumstances, apparently trifling, will occasion an alteration in these contrary electricities. It has been said, that of two equal substances rubbed together, that which suffers the greatest friction, or is most heated, acquires the

* That is by blowing with a pair of bellows upon it. By this means many electrics may be excited, and some better, if the air blown is hot, although in both cases very little electricity can be obtained.

negative electricity. Though this in many cases holds true with respect to silk ribbons, yet Mr. *Bergman* says, that if the ribbon, A, be black, it will never become positive, unless B be black likewise. With pieces of glass the effect is contrary; for, if they are both equal, the piece, A, which is drawn across the piece, B, becomes negative; and B, which suffers the greatest friction, becomes positive. Heating by fire produces the same effect as the greater friction. If one piece of glass be thicker than the other, the former becomes positive, the latter negative. Coloured glass, even when heated, becomes negative, if rubbed with common white glass. If a piece of blue glass is rubbed against a green one, the blue glass becomes strongly positive, &c. *Bergman*, Swedish Tran. 1765.

The electricities produced by hair and glass rubbed together seem to balance each other, and are therefore different according to the manner of rubbing and the quality of the hair.

Hair of a living animal, or hair newly cut, when rubbed with a glass tube lengthways, is positive; and here the glass, which suffers the greatest friction, is negative. But, if the glass tube be drawn across the animal's back, or across a skain of hair newly cut, the glass becomes positive. Old dry hair, rubbed on glass or on living hair, always becomes negative; but, if the hair is a little greased with tallow, the same effect is produced as with living hair. *Wilke*, Swed. Tran. 1769.

Electrics differ from each other with respect to the facility with which they are excited, their force when excited, and the power with which they retain the effects of the excitation.

Silk seems preferable to any other electric substance for exhibiting a permanent and strong attractive and repulsive power.

Glass appears to have the advantage in exhibiting the electric light, attraction, and repulsion in quick succession, in a very vigorous, though not a durable manner.

Negative electrics, as amber, gum-lac, sulphur, resin, and all resinous substances, exhibit the electric appearances for the greatest length of time. A single excitation is sufficient to make them do so for many weeks, in favourable circumstances. They are also remarkable for the strong electric powers which they communicate to conducting bodies that come in contact with them, and which they will continue to communicate for a considerable time.

It may be proper to observe here, that the two classes of electrics and non-electrics are not so strongly marked by nature, as to enable the electrician to arrange every substance with propriety: hence the same substance has been placed by different writers in a different class. Besides this, the electric properties of the same substance vary on a change of circumstances: thus, a piece of green wood is a conductor; the same piece, after it has been baked, becomes a non-conductor; charred, and formed into charcoal, it again conducts the electric fluid; but, when reduced to ashes, is impervious to it. But further, the distinctions themselves are very improper, as every substance is to a certain degree a conductor of this fluid.

ELECTRICITY IS MATTER.

That electricity is real matter, and not a mere property, is evident from a variety of circumstances. When it passes between bodies it divides the air, and puts it into those undulations which gives us the idea of sound. It emits the rays of light in every direction, and those rays are variously refrangible and colorific, as other light is: and, if light is acknowledged to be matter, it is contrary to reason and experience, that the thing which emits it should not likewise be material. Neither are the other senses unaffected at its presence; its smell is strongly phosphoreal or sulphureous: the sense of feeling is a witness of its presence, not only from the sparks which, when received from the conductor of a powerful machine, are pungent, and will pass through two or three persons standing on the ground, but also from the shock. A stream of electric matter has also evidently a subacid taste.

Though the electric fluid has been known and studied for many years, we are altogether ignorant of its real essence and nature; to me it seems probable, that it is fire or light connected with some terrestrial base. The analogies between the action of electricity and fire are very striking; some of these I shall point out in the words of two able philosophical writers. Fire, says Mr. *Jones*, is divided into three sorts, *solar*, *culinary*, and *elementary*; the solar is that fire which resides in the orb of the sun, as in its reservoir or fountain, and proceeds from it in the form of light. The culinary is that fire which is kindled on earth by artificial means, and burns in any sort of fuel. The elementary is that subtile fluid, which resides constantly in all gross bodies, and is not necessarily distinguished by its heat as culinary fire; by its light, as solar or sidereal fire; but is known by other effects, even in a cold invisible state.

If it be true, that natural effects are not to be ascribed to many different means or agents, where fewer will suffice, these three should be considered as one and the same fluid, because they have the same properties and the same effects. The solar fire will burn in fuel, and act in solid matter with greater effect than the most violent fire of a furnace. The culinary fire will promote vegetation, and ripen fruits like the sun. The elementary, or electric fire, will light a candle and fire gun-powder, like the culinary; will afford a spectrum of the seven primordial colours, in common with the solar rays, or the light of an ordinary fire; and will throw metals into fusion with a violent scorching heat. Fire is brought into action by friction, as well as electricity. Fire dilates all bodies. The electric fluid has also a dilating power, which is evident from its action on a thermometer; though, in general, the force with which bodies cohere together is greater than the dilating power of electricity.

Fire promotes and accelerates vegetation as well as germination. Electricity, whether positive or negative, does the same.

Electricity, as well as fire, accelerates evaporation.

Fire and electricity accelerate the motion of the blood.* Lest fear, constraint, or attention to the experiment, might accelerate the pulse, and thus be attributed to electricity, Mr. *Archard* made the experiment on a dog when asleep, and always found, that the number of pulsations were increased when the animal was electrified.

The experiment made by Mr. *Archard* on the eggs of a hen, and by others on the eggs of moths, proves that electricity, as well as heat, favours the

* This position has been much controverted, and it seems clear, from modern experiment, that simple electricity does not accelerate the pulse.

developement of those animals. The electric fluid, in common with fire, will throw metals into fusion.

If substances with equal degrees of heat touch each other, the heat is diffused uniformly between them. In the same manner, if two bodies with unequal degrees, or different kinds of electricity, touch each other, an equilibrium will be established.

If bodies of different kinds, and of equal degrees of heat, are placed in a medium of a different temperature, they will all acquire, at the end of a certain time, the same degree of heat. There is a considerable difference, however, in the space of time in which they acquire the temperature of the medium: *ex. gr.* metals take less time than glass to acquire or lose an equal degree of heat.

On an attentive examination of the bodies which receive and lose their heat soonest, when they are placed in mediums of different temperature, they will be found to be the same which receive and lose their electricity with the greatest facility. Metals, which become warm or grow cool the quickest, are the substances which receive and part with their electricity soonest. Wood, which requires more time to be heated or cooled, receives and loses electricity slower than metals. Lastly, glass and resinous substances, which receive and lose slowly the electric fluid, acquire with difficulty the temperature of the medium which surrounds them.

If one extremity of an iron rod be heated red-hot, the other extremity, though the bar is several feet long, will become so warm in a little time that the hand cannot hold it; because the iron conducts heat readily: but a tube of glass, only a few inches long, may be held in the hand even while the other end is melting. The electric fluid, in the same manner, passes with great velocity from one end of a rod of iron to the other; but it is a considerable time before a tube of glass, at one end of which an excited electric is held, will give electric signs at the other.

These observations prove, that several bodies that receive and lose with difficulty their actual degree of heat, receive and lose also with difficulty their electricity. To determine if this law is general, and what are the exceptions to it, will require a variety of experiments.

EXPERIMENT VII. *shews us that the electric powers may be put in action by heat and cold*; it was originally made by Mr. *Canton.* He procured some thin glass balls, of about an inch and an half in diameter, with stems or tubes about eight or nine inches in length, and electrified them, some positively on the inside, others negatively, and then sealed them hermetically; soon after, he applied the naked balls to his electrometer, and could not observe the least sign of their being electrical; but, holding them at the fire, at the distance of five or six inches, they became strongly electrical in a short time, and more so when they were cooling. These balls would, every time they were heated, give the electric power to, or take it from other bodies, according to the plus or minus state of it within them. Heating them frequently diminished their power, but keeping one of them under water a week did not in the least impair it. The balls retained their virtue above six years.

The tourmalin, and many other precious stones, are also known to acquire electricity by heat. The tourmalin has always at the same time a positive and negative electricity; one side of it being in one state, the other in the opposite. These powers may be excited by friction and by heat; nay, even by plunging it in boiling water.*

EXPERIMENT VIII. *shewing the action of an electric fluid on a thermometer.* Insulate a sensible mercurial thermometer, and place the bulb be-

* This curious stone is ranked as a hard semi-pellucid fossil; is generally of a deep red, or purple colour, about the size of a small walnut; it is common in several parts of the East Indies, particularly in the island of Ceylon. The Linnæan name is *lapis electricus*; and, from its property of attracting the ashes when laid near the fire, the Germans call it *ascbentrickker*.

EDIT.

tween two balls of wood, one affixed to the conductor, the other communicating with the ground; and the electric fluid, in passing between the two balls, will raise the mercury in the thermometer considerably. With a cylinder of about seven inches and an half in diameter, the fluid passing from a ball of lignum vitæ to a ball of beech, and thence to the ground, elevated the quicksilver in the thermometer from 68° to 110°, repeatedly to 105°. The thermometer was raised from 68° to 85°, by the fluid passing from a point of box to a point of lignum vitæ; from 67° to 100°, from a point of box to a ball of box; from 66° to 100°, from a ball of box to a brass point; from 69° to 100°, from ball to ball; the bulb of the thermometer covered with flannel.*

* The bulb of the thermometer must be quite detached from the scale, or with a contrivance to occasionally admit the scale at least three inches above the bulb, to be turned away from the tube. Edit.

CHAP. III.

OF THE ELECTRICAL MACHINE, WITH DIRECTIONS FOR EXCITING IT.

As soon as the properties of electricity were in some measure developed, the philosopher and the artist concurred in contriving and executing a variety of machines to excite and accumulate this extraordinary agent. The greater part of these have been laid aside, in proportion as the science advanced, and its boundaries were extended. I shall, therefore, only describe that electric machine which is now in general use, whose construction is simple, and well adapted to produce the electric fluid in great quantities, and transmit it in full and continued streams to the prime conductor.

That the operator may succeed in producing this effect, I shall first enumerate those parts of the machine which require most attention; then describe the machine itself; and afterwards give instructions to enable him to excite it powerfully.

The following are the parts of an electrical machine, which fall more immediately under the care of an electrician.

1. The electric, or the glass cylinder, which is to be excited.

2. The mechanical contrivances by which the electric is put in motion.

3. The cushion and its appendages.

4. The conductor or conductors.

Plate 1, *fig.* 8, and the figure in the frontispiece, represent two electrical machines made on the most approved construction. They are both mounted and used in the same manner, and differ only in the mechanism by which the cylinder is put in motion.

The glass cylinder, H G, of the machine, which is represented in *fig.* 8, is put in motion by a simple winch, U, which is less complicated than the multiplying wheel, and therefore not so liable to be out of order; it is easier to manage, and may, in proportion to its size, be more powerfully excited than those with a multiplying wheel. Many practical electricians, however, prefer a machine which is moved by a multiplying wheel, as it fatigues the operator less than that which is moved by a simple winch; while, at the same time, a moderate increase of velocity in the cylinder is thought by some to augment the momentum of the electric fluid, and produce a greater quantity of it in the same time; and that, when the machine is fixed to a table, the position of the lower multiplying wheel is more advantageous to the operator, giving him a greater power over the cylinder, and fatiguing him less: it may also be turned with the right hand, which cannot be done conveniently with the other. It may be proper to remark, that those with a simple winch are somewhat less in expense than those with a multiplying wheel.

A B C represent the mahogany or wooden basis of the machine.

D and E, the two perpendicular supports, which sustain or carry the glass cylinder, F G H I. These two pillars, for a more perfect insulation, are sometimes made of glass.

The axis of the cap, K, passes through the support, D; on the extremity of this axis either a simple winch is fitted, or a pulley for to use with the multiplying wheel.

The axis of the other cap runs in a small hole which is made in the top of the support, E.

O P is the glass insulating pillar to which the cushion is fixed; T, a brass screw at the bottom of this pillar, which is to regulate the pressure of the cushion against the cylinder. This adjusting screw is peculiarly advantageous. By it, the operator is enabled to lessen or increase gradually the pressure of the cushion; which it effects in a much neater manner, than it is possible to do when the insulating pillar, as in some machines, is fixed on a sliding board. The pillar is sometimes cemented into a wooden socket, jointed with hinges, and also moved by a regulating screw, T. This likewise answers very well.

g h i, a piece of silk that comes from the under edge of the cushion, and lies on the cylinder, passing between it and the cushion, till it nearly meets the collecting points of the conductor.

Y Z represents the positive prime metallic conductor, or that which takes the electric fluid by collecting points immediately from the cylinder; L M, the glass pillar by which it is supported and insulated, and V X a wooden foot or base for the glass pillar. In general, electrical machines are sold with a single conductor; though there are many experiments where two are convenient, and from some improvements lately made in the apparatus, they are rendered exceeding proper for experimental inquiries.*

DESCRIPTION OF THE MEDICAL ELECTRICAL MACHINE AND APPARATUS, BY THE EDITOR.

The articles shewn in the frontispiece represent a complete electrical machine and apparatus for

* A conductor fixed to, or connected with the insulated rubber, is called the negative conductor; and, where negative electricity is desired, is indispensably necessary to be applied to, or connected with, the rubber of the machine. I have thought it proper to subjoin here a particular description of the apparatus represented in the frontispiece. Edit.

medical purposes, as actually applied in the practice. A B C is the mahogany basis, which in this machine is in the form of a chest, with a drawer to hold the several small articles when not in use. E G H I, the glass cylinder which should be at least nine inches in diameter; O P, the glass pillar insulating the rubber above; T, the regulating screw which acts against a jointed socket, into which the pillar is cemented; *g h i*, the flap of silk; *a b*, the pulley; *c d*, the multiplying wheel. There are several unequal sized grooves in the circumferences of the pulley and wheel, to suit the variable extent of the catgut band after much use. A simple winch is sometimes made to fix on the axis, instead of the pulley, *a b*; so that in case of an accident of the band breaking, or at the pleasure of the operator, the winch only may be used in order to put the cylinder into motion. Y Z is the form of the prime metallic conductor, which in this figure is represented of the T shape, a form more convenient than essential. L M the insulating glass pillar; V X, the wooden foot, like to the preceding machine; *c e f d*, the improved medical bottle, suspended from the conductor by the brass ball and wire fixed thereto; *a b* on the conductor, the discharging electrometer, consisting of a bent piece of glass, and sliding wire and ball *b*. This sliding wire is useful to regulate the degree of charge given to the jar *c e f d*, or any other jar applied to the conductor, and from which a patient is to be electrified, the strength of the discharged electricity being in proportion to the distance of the ball from the conductor. *Lane*'s discharging electrometer, as fixed to a jar, is shewn at F E D G I, *plate* 5, *fig*. 85; but the preceding one may be considered preferable, as it serves universally for any jar applied to the conductor. *k*, *l*, in the hands of the human figure, represent two glass handle directors, connected with two conducting wires or chains, *m*, *n*. The child in the figure is represented as receiving a small electric shock in her right arm, as far as from one ball to the other of the directors, *k*, *l*.

When the cylinder is put into motion, the jar, *c e f d*, is charged in an instant by the conductor Y Z; the electric fluid becomes thence sufficiently condensed to discharge itself through the conductor and air to the electrometer, *a b*, and thence by the chain, *m*, to the director *l*, entering the arm of the child, and going to the other director *k*, and chain *n*, to the hook, *d*, or outside of the jar. Thus the electric circuit is completed, and the patient electrified; the repetition of these discharges constitute the number of shocks, the strength of which is regulated by the discharging electrometer, *a b*. It is evident, that wherever the balls of the directors are applied, the shock will pass through that part of the patient only which is between them. One chain or wire is always connected to a director and outside of a jar, and another director to the discharging electrometer. The handles of the directors are made of glass, to insulate the operator from any effect by the electric fluid in its circuit.

There is a small glass tube, partly coated with tin-foil, placed within the medical jar, *c e f d*; a wire passes through the brass cap, to communicate with the inside of this tube; another wire also passes through another hole in the cap, communicating with the inside coating of the jar; so that by taking out either of these wires, either the larger jar or smaller tube will be charged, according to the communicating wire left in. When the short wire only is left in, the small charges given to the tube are of very considerable utility in medical practice; the shocks from it being of the most slender kind, and cannot cause any disagreeable effects or apprehension to timid patients, and, by the electrometer, can be diminished to a very small degree, not more in effect than a simple spark from the prime conductor only. When the strongest shocks are required, the wires must be left both in the tube and jar.

A drawer is sometimes made in the table, instead of one in the basis of the machine, A B C, to hold the auxiliary articles. This table is sometimes made in the form of a chest with two drawers and folding doors, so as to hold both the machine and apparatus when done with, keeping them clean and dry, and forming a piece of neat table furniture in a room. But all these arrangements lay at the pleasure of the purchaser, and are according to the price given by him.

If the patient is not to be electrified by shocks, but by sparks, he is to stand or be placed on the insulated stool, *plate* 2, *fig.* 8, and simply to hold a wire or chain communicating with the brass ball and wire fixed into the end of the conductor, as at Y. The sparks to be taken from him by the ball of the balls and wire shewn at K, or, if the operator objects to a small sensation on himself in taking the sparks, by the ball and wire with the glass handle K, to which a chain or wire must be fastened to communicate with the ground, and along which the electric fluid will pass without affecting the person taking the sparks in the least sensible manner. At each end of the wires of the balls and wires, shewn at N and K, are brass and wooden points, to be used for taking fine streams of the electric fluid of different densities from the eyes, and from patients when the sparks might be too pungent or irritating.

Q is a representation of an instrument made of glass, with a sliding wire and point, and is found a very convenient article to take the electric stream or aura from an eye of a patient. The wire is to be connected with the chain or wire connected with the conductor, or simply held in the hand when the patient is placed upon the insulated stool. The strength of the sparks or aura will be according to the degree of excitation of the glass cylinder, and the clean and dry state of the rest of the apparatus.

DIRECTIONS FOR KEEPING THE MACHINE IN ORDER.

Before the electrical machine is put in motion, examine those parts which are liable to wear, either from the friction of one surface against another, or to be injured by the dirt that may insinuate itself between the rubbing surfaces.

If any grating or disagreeable noise is heard, the place from whence it proceeds must be discovered, wiped clean, and rubbed over with a small quantity of tallow: a little sweet oil or tallow should also occasionally be applied to the axis of the cylinder; for which purpose, there are usually two screws at the top of the pillar D, which, when unscrewed, disengage a wooden piece, and cause the axis to be freed from its supports.

The screws that belong to the frame should be examined, and if they are loose, they should be tightened.

The different working parts of the machine having been looked into and put in order, the glass cylinder, and the pillars which support the cushion and conductor should be carefully wiped with a dry warm old silk handkerchief, to free them from the moisture which glass attracts from the air; being particularly attentive to leave no moisture at the ends of the cylinder, as any damp on these parts carries off the electric fluid, and lessens the force of the machine. In very damp weather, or when the machine has been laid aside for some time, it will be proper to dry and warm the whole machine, by placing it before, but also at some distance from the fire.

Take care that no dust, loose threads, or filaments, adhere to the cylinder, its frame, the conductors, or their insulating pillars; because these will gradually dissipate the electric fluid, and prevent the machine from acting powerfully.

Rub the glass cylinder first with a clean, coarse, dry, warm cloth, or a piece of wash leather, and then with a piece of dry, warm, soft silk; do the same to all the glass insulating pillars of the machine and apparatus. Varnished glass pillars must be rubbed more lightly than the cylinder or unvarnished glass. Glass varnished is less susceptible of moisture.

A hot iron may in some cases be placed on the foot of the conductor, to evaporate the moisture which would otherwise injure the experiments.

OF THE CIRCUMSTANCES NECESSARY TO BE ATTENDED TO, IN ORDER TO EXCITE A LARGE QUANTITY OF THE ELECTRIC FLUID.

In order to find out an effectual mode of exciting powerfully an electrical machine, it is necessary to frame some idea of the mechanism by which the cylinder extracts the electric fluid from the cushion, and those bodies which are connected with it; I have, therefore, subjoined those conjectures on which I have worked, and by which I have been able to excite, in the most powerful manner, the machines which have passed through my hands; setting out on this supposition, that the friction is between an electric and non-electric, and that the circumstances are the most favourable when these are the most perfect of their kind.

It is probable that the resistance of the air is lessened, or a kind of vacuum is produced, where the cushion is in close contact with the cylinder; that the electric matter, agreeable to the law observed by all other elastic fluids, is pressed towards that part where it finds least resistance: the same instant, therefore, that the cylinder is separated from the cushion, the fire issues forth in abundance, because the resistance made to it by the action of the atmosphere is lessened at that part. A further circumstance is also to be taken into this hypothesis, namely, the effect which arises from the destruction of the attraction or cohesion between the cylinder and cushion. The more perfect the continuity is made, and the quicker the solution of it, the greater is the quantity which will proceed from the cushion. But, as the fluid in this situation will enter with avidity every conducting substance that is near it, if any amalgam lies above that part of the cushion which is in contact with the cylinder, it will absorb and carry back part of the electric fire to the reservoir from whence it was extracted.*

If these conjectures be true, to excite an electrical machine effectually, we must,

1. Find out those parts of the cushion which are pressed by the glass cylinder.

2. Apply the amalgam only to those parts.

3. Make the line of contact between the cylinder and cushion as perfect as possible.

* The glass cylinders, as made at the glass manufactories, are generally somewhat irregular on their surfaces, and more generally of unequal diameters at their ends. Some years ago I contrived a plain bent metallic spring, to act between two narrow flat boards, to which the stuffed cushion is glued; which has been found to yield to the several irregularities in the cylinder while in motion, and yet keep a constant and steady pressure on its surface. We now in general apply it to all the machines of our construction. EDIT.

4. Prevent the fire that is collected from escaping.

About the year 1772, I applied a loose flap of leather to the front of the cushion; the amalgam was spread over the whole of the flap; the cushion was then put in its place, and the loose flap of leather doubled down, or rather turned in, more or less, till by successive experiments that situation was discovered which produced the greatest effect: for, by this means, the quantity of amalgam acting against the cylinder was lessened, and the true line of contact in some measure ascertained. Hence I was naturally led to contract the breadth of the cushion, a circumstance which has been since universally adopted by all electricians; and thus, much of the trouble to which we were formerly obliged to submit, is done away.

The amalgam is to be placed on that part of the silk flap which bears against the cushion; the cylinder is to be rubbed with a piece of leather which is covered with amalgam, which will render the contact between the cylinder and cushion more perfect, because it fills the smaller pores of the glass with amalgam, and deposits the superfluous particles on the cushion. When the cylinder is rubbed with the amalgamed leather, that part of the oiled or black silk which lies above the cushion is to be turned back; and if by accident any particles of amalgam stick to it, they must be wiped off carefully. If the machine has not been used for some time, it will be proper to place it for a few minutes before a fire, and to take off the cushion and dry the silk thereof.

If the electricity of the cylinder grows less powerful, it is easily renewed by rubbing the cylinder with the amalgamed leather,* or by occasionally altering the pressure of the rubber before described on the cylinder, by turning the adjusting screw.

A very small quantity of tallow placed over the amalgam, is observed to give more force to the electric powers of the cylinder; the same end is answered by rubbing the cylinder with a coarse cloth that has been greased a little, and afterwards wiping it with a clean cloth.†

Experiment ix. When the cylinder is put into good action, a number of circular lines of

* A round piece of leather, about two or three inches in diameter, glued on a piece of pasteboard about four inches in diameter; on this, a little tallow and some amalgam must be previously spread: then the whole becomes an useful article to hold in the hand, and apply to the cylinder while in motion, when necessary. Edit. A Soft bung or piece of Cork cov'd with leather does better—

† I think it proper to observe here, that if a machine is kept in a dry room, free of dust and damp, it is scarcely necessary to do more than wipe and warm it somewhat before a fire, and apply the amalgamed leather to the cylinder, or spread some amalgam on the leather of the cushion. Edit.

fire will issue from the cushion; present a row of metallic points towards these, and they will disappear. This experiment shews, the conducting substance collects the electric fluid before it can take those appearances, or be dissipated into the air.

Hence we learn, that to prevent a loss of the electric fluid which is excited, we must prevent the air from acting on the fluid which is put in motion by the excitation; because the air not only resists the emission of the fluid, but also dissipates what is collected on account of the conducting substances which are continually floating in it.

These ends are effectually answered, by letting a non-conducting substance, as a piece of black or oiled silk, proceed from the line of contact to the collecting points of the prime conductor, and placing these points within its atmosphere. The streams of fire, which proceed from the cushion over the cylinder, shew whether the cushion bears uniformly against the cylinder; for they are most copious and dense at those parts where the pressure is greatest, but are uniformly dense when the pressure is equable.

When the zinc amalgam is used, the silk will sometimes adhere so strongly to the cylinder, as to render it very difficult to turn. To obviate this, wipe the silk perfectly clean, and then rub it over with a very small qnantity of aurum musivum,* or a little whiting.

The operator ought not to think his machine in good order, till it pours forth the fire in great abundance, and strong dense sparks are obtained in quick succession from the conductor. When the conductor is removed, the fire should sprinkle round the cylinder, and throw out many beautiful brushes of light.

Two kinds of amalgam are much in request at present. One is made of quicksilver five parts, zinc one part, which are melted together in an iron ladle with a small quantity of bees-wax:† the other is the aurum musivum of the shops. To make either amalgam adhere closely to the silk, it is necessary to grease it, wipe off the superfluous grease, and then spread the amalgam.

The following experiment seems to illustrate and confirm the foregoing conjectures on the mechanism by which the fluid is extracted from the cushion, and those bodies which are connected with it.

* The objection I make to this drug is, that it is somewhat offensive in smell, and disagreeable to the hands and articles with which it may happen to be in contact. Edit.

† See Dr. *Higgins*'s method noticed by Mr. *Nicholson*, in paragraph 22, of the following section. Edit.

EXPERIMENT X. *On the effects of a solution of continuity.* Break a stick of sealing-wax in two pieces; those extremities that were contiguous will be found electrified with contrary powers; one will be positively, the other negatively, electrified.

Since the third edition of this work, Mr. *Nicholson* has made many experiments on the nature of excitation, and on the most efficacious methods of exciting an electric machine powerfully; they were communicated to the Royal Society, and read before them, June 25, 1789, and have since been published in the Philosophical Transactions; I have, therefore thought it a duty to add them to this edition of the work, as containing much important matter.

EXPERIMENTS AND OBSERVATIONS ON THE EXCITATION OF ELECTRICITY, BY WILLIAM NICHOLSON.

ON THE EXCITATION OF ELECTRICITY.

1. A glass cylinder was mounted, and a cushion applied with a silk flap, proceeding from the edge of the cushion over its surface, and thence half round the cylinder. The cylinder was then excited by applying an amalgamed leather in the usual manner. The electricity was received by a

conductor, and passed off in sparks to *Lane*'s electrometer. By the frequency of these sparks, or by the number of turns required to cause the spontaneous explosion of a jar, the strength of the excitation was ascertained.

2. The cushion was withdrawn about one inch from the cylinder, and the excitation performed by the silk only. A stream of fire was seen between the cushion and the silk; and much fewer sparks passed between the balls of the electrometer.

3. A roll of dry silk was interposed, to prevent ths stream from passing between the cushion and the silk. Very few sparks then appeared at the electrometer.

4. A metallic rod, not insulated, was then interposed, instead of the roll of silk, so as not to touch any part of the apparatus. A dense stream of electricity appeared between the rod and the silk, and the conductor gave very many sparks.

5. The knob of a jar being substituted in the place of the metallic rod, it became charged negatively.

6. The silk alone, with a piece of tin-foil applied behind it, afforded much electricity, though less than when the cushion was applied with a light pressure. The hand, being applied to the silk as a cushion, produced a degree of excitation seldom equalled by any other cushion.

7. The edge of the hand answered as well as the palm.

8. When the excitation by a cushion was weak, a line of light appeared at the anterior part of the cushion, and the silk was strongly disposed to receive electricity from any uninsulated conductor. These appearances did not obtain when the excitation was by any means made very strong.

9. A thick silk, or two or more folds of silk, excited worse than a single very thin flap. The silk which the milleners call Persian was used.

10. When the silk was separated from the cylinder, sparks passed between them; the silk was found to be in a weak negative, and the cylinder in a positive state.

The foregoing experiments shew that the office of the silk is not merely to prevent the return of electricity from the cylinder to the cushion, but that it is the chief agent in the excitation; while the cushion serves only to supply the electricity, and perhaps increase the pressure at the entering part. There likewise seems to be little reason to doubt, but that the disposition of the electricity to escape from the surface of the cylinder is not prevented by the interposition of the silk, but by a compensation after the manner of a charge; the silk being then as strongly negative as the cylinder is positive:* and lastly, that the line of light between the silk and cushion, in weak excitations, does not consist of returning electricity, but of electricity which passes to the cylinder, in consequence of its not having been sufficiently supplied, during its contact with the rubbing surface.

11. When the excitation was very strong in a cylinder newly mounted, flashes of light were seen to fly across its inside, from the receiving surface to the surface in contact with the cushion, as indicated by the brush figure. These made the cylinder ring, as if struck with a bundle of small twigs. They seem to have arisen from part of the electricity of the cylinder taking the form of a charge. This appearance was observed in a nine-inch and a twelve-inch cylinder, and the property went off in a few weeks. Whence it appears to have been chiefly occasioned by the rarity of the internal air, produced by handling, and probably restored by gradual leaking of the cement.

12. With a view to determine what happens in the inside of the cylinder, recourse was had to a plate machine. One cushion was applied with its silken flap. The plate was nine inches in dia-

* The powers are always separated in excitation. See *Eeles's* system. G. A.

meter, and two-tenths of an inch thick. During the excitation, the surface opposite the cushion strongly attracted electricity, which it gave out when it arrived opposite the extremity of the flap. So that a continual stream of electricity passed through an insulated metallic bow terminating in balls, which were opposed, the one to the surface opposite the extremity of the silk, and the other opposite the cushion; the former ball shewing positive, and the latter negative signs. The knobs of two jars being substituted in the place of these balls, the jar, applied to the surface opposed to the cushion, was charged negatively, and the other positively. This disposition of the back surface seemed, by a few trials, to be weaker the stronger the action of the cushion, as judged by the electricity on the cushion side.

Hence it follows, that the internal surface of a cylinder is so far from being disposed to give out electricity during the friction by which the external surface acquires it, that it even greedily attracts it.

13. A plate of glass was applied to the revolving plate, and thrust under the cushion in such a manner as to supply the place of the silk flap. It rendered the electricity stronger, and appears to be an improvement of the plate machine; to be admitted, if there were not essential objections against the machine itself.

14. Two cushions were then applied on the opposite surfaces with their silk flaps, so as to clasp the plate between them. The electricity was received from both, by applying the finger and thumb to the opposite surfaces of the plate. When the finger was advanced a little towards its correspondent cushion, so that its distance was less than between the thumb and its cushion, the finger received strong electricity, and the thumb none; and, contrariwise, if the thumb were advanced beyond the finger, it received all the electricity, and none passed to the finger. This electricity was not stronger than was produced by the good action of one cushion applied singly.

15. The cushion in par. 12, gave most electricity when the back surface was supplied, provided that surface was suffered to retain its electricity till the rubbed surface had given out its electricity.

From the two last paragraphs it appears, that no advantage is gained by rubbing both surfaces; but that a well-managed friction on one surface will accumulate as much electricity as the present methods of excitation seem capable of collecting; but that, when the excitation is weak, on account of the electric matter not passing with sufficient facility on the rubbed surface, the friction enables the opposite surface to attract or receive it, and if it be supplied, both surfaces will pass off in the positive state; and either surface will give out more electricity than is really induced upon it, because the electricity of the opposite surface forms a charge. It may be necessary to observe, that we are speaking of the facts or effects produced by friction; but, how the rubbing surfaces act upon each other to produce them, whether by attraction, or otherwise, is not here the subject of inquiry.

It will hereafter be seen, that plate machines do not collect more electricity than cylinders, in the hands of the electrical operators of this metropolis, do with half the rubbed surface; which is a corroboration of the inference here made.

16. When a cylinder is weakly excited, the appearances mentioned in par. 8, are more evident the more rapid the turning. In this case, the avidity of the surface of the cylinder beneath the silk is partly supplied from the edge of the silk which throws back a broad cascade of fire, sometimes to the distance of above twelve inches. From these causes it is that there is a determinate velocity of turning required to produce the maximum of intensity in the conductor. The stronger the excitation, the quicker may be the velocity; but it rarely exceeds five feet of the glass to pass the cushion in a second.

17. If a piece of silk be applied to a cylinder, by drawing down the ends, so that it may touch

half the circumference, and the cylinder be then turned and excited by applying the amalgamed leather, it will become very greedy of electricity during the time it passes under the silk. And if the entering surface of the glass be supplied with electricity, it will give it out at the other extremity of contact; that is to say, if insulated conductors be applied to the touching ends of the silk, the one will give, and the other receive electricity, until the intensities of their opposite states are as high as the power of the apparatus can bring them; and these states will be instantly reversed by turning the cylinder in the opposite direction.

As this discovery promises to be of the greatest use in electrical experiments, because it affords the means of producing either the plus or minus states in one and the same conductor, and of instantly repeating experiments with either power, and without any change of position or adjustment of the apparatus, it evidently deserved the most minute examination.

18. There was little hope (par. 6) that cushions could be dispensed with. They were therefore added; and it was then seen, that the electrified conductors were supplied by the difference between the action of the cushion which had the advantage of the silk and that which had not; so that the naked face of the cylinder was always in

a strong electric state. Methods were used for taking off the pressure of the receiving cushion; but the extremity of the silk, by the construction, not being immediately under the cushion, gave out large flashes of electricity with the power that was used. Neither did it appear practicable to present a row of points, or other apparatus, to intercept the electricity which flew round the cylinder; because such an addition would have materially diminished the intensity of the conductor, which in the usual way was such as to flash into the air from rounded extremities of four inches diameter, and made an inch and half ball become luminous and blow like a point. But the greatest inconvenience was, that the two states with the backward and forward turn were seldom equal; because the disposition of the amalgam on the silk, produced by applying the leather to the cylinder in one direction of turning, was the reverse of what must take place when the contrary operation was performed.

Notwithstanding all this, as the intensity with the two cushions was such as most operators would have called strong, the method may be of use.

19. The more immediate advantage of this discovery is, that it suggested the idea of two fixed cushions with a moveable silk flap and rubber. Upon this principle, which is so simple and obvious, that it is wonderful it should have been so

long overlooked, a machine was constructed by Mr. *Nicholson* with one conductor, in which the two opposite and equal states are produced by the simple process of loosening the leather rubber, and letting it pass round with the cylinder, to which it adheres, until it arrives at the opposite side, where it is again fastened. A wish to avoid prolixity prevented his describing the mechanism by which it is let go and fastened in an instant, at the same time that the cushion is made either to press or is withdrawn, as occasion requires.

20. Although the foregoing series of experiments naturally lead us to consider the silk as the chief agent in the excitation; yet, as this business was originally performed by a cushion only, it becomes an object of inquiry to determine what happens in this case.

21. The great *Beccaria** inferred, that in a simple cushion, the line of fire, which is seen at the extremity of contact from which the surface of the glass recedes, consists of returning electricity; and Dr. *Nooth* grounded his happy invention of the silk flap upon the same supposition. The former asserts, that the lines of light both at the entering and departing parts of the surface are absolutely similar; and thence infers, that the cushion receives on the one side as it certainly

* Philosophical Transactions, vol. lvi. p. 117.

does on the other. Mr. *Nicholson* finds, however, that the fact is directly contrary to this assertion, and that the opposite inference ought to be made, as far as this indication can be reckoned conclusive; for the entering surface exhibits many luminous perpendiculars to the cushion, and the departing surface exhibits a neat uniform line of light. This circumstance, together with the consideration that the line of light behind the silk in par. 8, could not consist of returning electricity, shewed the necessity of farther examination. Mr. *Nicholson* therefore applied the edge of the hand as a rubber, and by occasionally bringing forward the palm, he varied the quantity of electricity which passed near the departing surface. When this was the greatest, the sparks at the electrometer were the most numerous. But, as the experiment was liable to the objection, that the rubbing surface was variable, Mr. *Nicholson* pasted a piece of leather upon a thin flat piece of wood, then amalgamed its whole surface, and cut its extremity off in a neat right line close to the wood. This being applied by the constant action of a spring against the cylinder, produced a weak excitation, and the line where the contact of the cylinder and leather ceased, as abruptly as possible, exhibited a very narrow fringe of light. Another piece of wood was prepared of the same width as the rubber, but one quarter of an inch thick, with its edges rounded, and its whole surface covered with tin-foil. This was laid on the back of the rubber, and was there held by a small spring, in such a manner as that it could be slided onward, so as occasionally to project beyond the rubber, and cover the departing and excited surface of the cylinder, without touching it. The sparks at the electrometer were four times as numerous when this metallic piece was thus projected; but no electricity was observed to pass between it and the cylinder. The metallic piece was then held in the hand to regulate its distance from the glass; and it was found, that the sparks at the electrometer increased in number as it was brought nearer, until light appeared between the metal and the cylinder, at which time they became fewer the nearer it was brought, and at last ceased when it was in contact.

The following conclusions appear to be deducible from these experiments. 1. The line of light on a cylinder departing from a simple cushion consists of returning electricity. 2. The projecting part of the cushion compensates the electricity upon the cylinder, and by diminishing its intensity, prevents its striking back in such large quantities as it would otherwise do. 3. That if there were no such compensation, very little of the excited electricity will be carried off; and, 4. That the compensation is diminished, or the intensity increased, in an higher ratio than that of the distance of the compensating substance; because if it were not, the electricity which has been carried off from an indefinitely small distance, would never fly back from a greater distance and from the edge of light.

22. Mr. *Nicholson* hopes the considerable intensity he speaks of will be an apology for describing the manner in which it was produced, wishing the theory of this very obscure process were better known; but no conjecture is worth mentioning. The method is as follows:

Clean the cylinder, and wipe the silk.

Grease the cylinder by turning it against a greased leather till it is uniformly obscured. The tallow of a candle was used.

Turn the cylinder till the silk flap has wiped off so much of the grease, as to render it semi-transparent.

Put some amalgam on a piece of leather, and spread it well, so that it may be uniformly bright. Apply this against the turning cylinder. The friction will immediately increase, and the leather must not be removed until it ceases to become greater.

Remove the leather, and the action of the machine will be very strong.

The rubber, as before observed, consists of the silk flap pasted to a leather, and the cushion is pressed against the silk by a slender spiral spring in the middle of its back. The cushion is loosely retained in a groove, and rests against the spring only, in such a manner, that by a sort of libration upon it as a fulcrum, it adapts itself to all the irregularities of the cylinder, and never fails to touch in its whole length. There is no adjustment to vary the pressure, because the pressure cannot be too small when the excitation is properly made. Indeed, the actual withdrawing of the cushion to the distance of one-tenth of an inch from the silk, as in par. 2, will not materially affect a good excitation.

The amalgam is that of Dr. *Higgins*, composed of zinc and mercury. If a little mercury be added to melted zinc, it renders it easily pulverable, and more mercury may be added to the powder to make a very soft amalgam. It is apt to crystallize by repose, which seems in some measure to be prevented by triturating it with a small proportion of grease: and it is always of advantage to triturate it before using.

A very strong excitation may be produced by applying the amalgamed leather to a clean cylinder with a clean silk. But it soon goes off, and is not so strong as the foregoing, which lasts several days.

23. To give some distinctive criterions by which other electricians may determine whether

the intensity they produce exceeds or falls short of that which this method affords, I shall mention a few facts.

With a cylinder seven inches diameter, and cushion eight inches long, three brushes at a time constantly flew out of a three-inch ball in a succession too quick to be counted, and a ball of one and an half inch diameter was rendered luminous, and produced a strong wind like a point. A nine-inch cylinder with an eight-inch cushion occasioned frequent flashes from the round end of a conductor four inches diameter: with a ball of two and an half inches diameter the flashes ceased now and then, and it began to appear luminous: a ball of one and an half inch diameter first gave the usual flashes; then, by quicker turning, it became luminous with a bright speck moving about on its surface, while a constant stream of air rushed from it; and lastly, when the intensity was greatest, brushes of a different kind from the former appeared. These were less luminous, but better defined in the branches; many started out at once with a hoarse sound. They were reddish at the stem, sooner divided, and were greenish at the point next the ball, which was brass. A ball of $\frac{4}{10}$ inch diameter was surrounded by a steady faint light, enveloping its exterior hemisphere, and sometimes a flash struck out at top. When the excitation was strongest, a few flashes struck out sideways. The horizontal diameter of the light was longest, and might measure one inch, the stem of the ball being vertical.

This last phenomenon is similar to a natural event related by M. *Laommi Baldwin*,* who raised an electrical kite in July 1771, during the approach of a severe thunder-storm, and observed himself to be surrounded by a rare medium of fire, which, as the cloud rose nearer the zenith, and the kite rose higher, continued to extend itself with some gentle faint flashes. Mr. *Baldwin* felt no other effect than a general weakness in his joints and limbs, and a kind of listless feeling; all which, he observes, might possibly be the effect of surprize, though it was sufficient to discourage him from persisting in any farther attempt at that time. He therefore drew in his kite, and retired to a shop till the storm was over, and then went to his house, where he found his parents and friends much more surprized than he had been himself; who, after expressing their astonishment, informed him, that he appeared to them, during the time he was raising the kite, to be in the midst of a large bright flame of fire, attended with flashings; and that they expected every moment to see him

* Memoirs of the American Academy, vol. i. p. 257.

fall a sacrifice to the flame. The same was observed by some of his neighbours, who lived near the place where he stood.

This fact is similar to another observed by M. *de Saussure* on the Alps, and both are referable to my luminous ball with the second kind of brush. The cloud must have been negative.

With a twelve-inch cylinder, and rubber of seven and an half inches, a five-inch ball gave frequent flashes upwards of fourteen inches long, and sometimes a six-inch ball would flash. I do not mention the long spark, because I was not provided with a favourable apparatus for the two large cylinders. The seven-inch cylinder affords a spark of ten inches three quarters at best. The nine-inch cylinder, not having its conductor insulated on a support sufficiently high, afforded flashes to the table which was fourteen inches distant. And the twelve-inch cylinder, being mounted only as a model or trial for constructing a larger apparatus, is defective in several respects. When the five-inch ball gives flashes, the cylinder is enveloped on all sides with fire, which rushes from the receiving part of the conductor. Points are not used, but in a simple machine the conductor is brought almost in contact with the cylinder. In this apparatus, the cushion to which the rubber is not applied serves that purpose.

24. These marks exhibit the intensity as deduced from simple electrifying. The rate of charging was nearly the same in all the three cylinders.

A large jar of 350 square inches, or near two and an half square feet, with an uncoated varnished rim, of more than four inches in height, was made to explode spontaneously over the rim. The jar, when broken, proved to be 0.082 inches thick on an average; and the number of square feet of the surface of the cylinder which was rubbed to produce the charge of one foot was, when least, 18.03, and when most, with good excitation, 19.34. The great machine at Harlem charges * a single jar of one foot square by the friction of 66.6 square feet, and charges its battery of 225 square feet at the rate of 94.8 square feet rubbed for each foot. The intensity of electricity on the surface of the glass is therefore considerably less than one-fourth of that here spoken of; but if we take the most favourable number 66.6 at the commencement of turning, and halve it on account of the unavoidable imperfection of a plate machine, as shewn in par. 14, it will be found, that the management applied to that machine

* To explode from the central wire, which, from some trials, I find to require less force than from coating to coating at equal distances.

would cause a cylinder to charge one square foot by the friction of thirty-three and an half square feet. It must be observed, however, that M. *Van Marum's* own machine, consisting of two plates thirty-three inches diameter, has only half the intensity, though he reckons it a very good one. This machine is about equal in absolute power to my nine-inch cylinder, with its short rubber; but it is near thirty times as dear in price. In all these deductions the computations are omitted for the sake of brevity, and because they are easily made. The data are found in the description of the Teylerian machine, and its continuation published at Harlem in the years 1785 and 1787.

The action of the cylinder, by a simple cushion or the hand, which excited the astonishment of all Europe, in the memory of our co-temporaries, was first improved by the addition of a leather flap; then by moistning the rubber; afterwards by applying the amalgam; and, lastly, by the addition of a silk flap. Now we find, by experiment, that we at present obtain upwards of forty times the intensity which the bare hand produces; and consequently that, since eighteen times our present intensity will equal the utmost we can now condense on strong glass, even in the form of a charge, we have a less step to take before we arrive at that amazing power, than our immediate predecessors have already made.

CHAP. IV.

OF THE FRANKLINIAN HYPOTHESIS. OBJECTIONS TO THIS HYPOTHESIS. EELES'S SYSTEM PREFERABLE TO THE FRANKLINIAN.

THE evidence of the external senses is obviously the primary principle from which all physical knowledge is derived; but whereas nature begins with causes, which after a variety of changes produce effects, the senses open upon the effects, and from them, through the slow and painful road of experiment and observation, ascend to causes.

Man appears upon the stage of this material system as upon a visionary theatre, in which he looks only upon the exterior of things, as the eye upon a flower that is full blown, or upon an insect in all the pride and beauty of its colours; without observing immediately the different stages through which they have passed, the different forms they have assumed, the different changes they have undergone, and without descending to the seeds and principles from which they spring, and which upon examination will be found totally different both in form and colour. In like manner are the senses, the ultimate criteria of all physical knowledge, liable to be imposed upon and deceived in regard to the qualities and causes, the powers and operations, of physical body.

The senses are, therefore, to be assisted by various observations taken with diligence and circumspection, and to be undeceived by different analyses, which divest nature of her external and compounded form, and lay open her internal mechanism and construction: their errors and misconceptions are to be corrected by the use of experiments of different kinds, which penetrate her inmost recesses, and descend to her remotest causes. By the application of such assistance they are enabled, not without difficulty, to leave behind the fallacious exterior, to pass from one appearance to another, and, as far as human research can go, to judge of the realities of things.

Nothing, perhaps, has contributed more to the establishment of truth, and the advancement of genuine science, than the transition from metaphysical reasoning to experimental philosophy. Mere conjecture, however plausible, or fondly embraced at first, affording at length but little satisfaction to the mind, we are constantly wishing for the evidence of facts; and finding but few speculative points, but what are liable to be controverted, we are obliged to seek for demonstrative proof, by adverting to practical investigation.*

* *Tatham's* Scale and Chart of Truth.

This is eminently true with respect to electricity; a field of inquiry, wherein fancy has, indeed, sufficiently exhibited her luxuriance. No other science has had more admirers, nor been subject in so short a space of time, to so great a variety of hopotheses: these have been changed, corrected, and improved, almost as often as the instruments and machines which have been made use of upon the occasion. Indeed, so little of the nature of electricity was known before the apparatus became considerably extended, that even the existence of the agent seems to have been a matter of speculation; but, after the instruments had demonstrated that such a fluid actually existed, the mode of that existence was altogether undetermined, and became a subject of much dispute.

Some have supposed the electric matter to be a kind of unctuous effluvia, arising by means of friction from substances termed electrics *per se*; others, the ether pointed out by Sir *Isaac Newton*, in the effects of which a certain subtile medium was concerned. Some called it elementary fire, and imagined it to be a modification of the fire they termed an element; while others conceived it to be a fluid distinct from chemical fire, but of a nature greatly resembling it.

After two opposite and remarkably distinct effects had been observed in the attractive and repulsive powers of electricity, according as they were excited in different substances, the theories of electricity became more complex; and a few gentlemen, with M. *du Fay* at their head, asserted the existence of two distinct fluids, which they called the vitreous and resinous electricity, in order to account for the different phenomena which they observed to arise from the excitation of such substances. To these hypotheses may be added the ingenious *Abbe Nollet's* doctrine of electrical affluences and effluences, which he so strenuously maintained.

When it was discovered that this twofold electricity might be procured by one and the same substance, and from the same machine, the subject appeared entirely in a new light, and the terms were presently changed from vitreous and resinous to those of positive and negative electricity, because they were then thought to be more adequate and expressive of the fact; and the appearances which were afterwards produced by means of this discovery seemed sufficient to establish at least the opinion that all electrical phenomena are effected by a fluid, extremely elastic, and attached to the particles of all other matter.

You have been already told, that as long as the electrical fluid is equally distributed among different substances, we cannot discover any sign of its existence; a striking proof of our incapacity of knowing the existence of certain substances otherwise than by their effects: as long as the electric fluid remains in its natural state, its effects are invisible, and we are totally insensible of its power; but whenever the equilibrium is disturbed, we are immediately sensible of its effects.

The electric fluid adheres to the surface of electrics more strongly than to the surface of conductors; and hence, when two such substances are rubbed together, part of the natural quantity belonging to the conductor adheres to the electric. Without this property, the existence of the electric fluid might never have been discovered. Had all bodies been possessed of an equal power of retaining and parting with the electric fluid, we should neither have had any means of exciting its appearance, nor have become in any measure sensible of its effects; but, because some substances freely admit of its passage through their pores, while others seem nearly impermeable to it, we can easily disturb the equilibrium by making the fluid pass from one body to another; and when it is thus collected, it is easily detained, by supporting the electrified body on such other substances, as will not admit of the fluid's passage.

That the principal source of the electric fluid is the earth, is a position now generally adopted, and may be rendered clear by insulating or cutting off the communication of the rubber from the earth, by means of glass or baked wood.

EXPERIMENT XI. *On the effects of insulating the cushion.* If the cushion and the conductor be both insulated, it is observed that less of the electric fluid is obtained, the more perfect the insulation is made.

Secondly. The same experiment, but with a machine furnished with two conductors, one connected with the cushion, the other as usual.

Turn the cylinder, and both will be electrified; but any electrified body which is attracted by the one will be repelled by the other: if they are brought sufficiently near to each other, sparks will pass between them, and they will act on each other stronger than on any other bodies. If they are connected together by a chain, the action of one destroys that of the other, and neither will exhibit any electric appearances, though the fire proceeds from the cushion to the conductor as before; but being immediately conveyed away from thence to the cushion, they both remain in their natural state.

The conductor connected with the cushion is said to be electrified negatively; that placed opposite thereto is said to be electrified positively.

To render this subject still plainer, if possible, I shall introduce another experiment, the more so as it is one which few writers mention.

EXPERIMENT XII. *Conductors electrified with the same power.* Electrify two conductors equally, by placing them before the cylinder, that is, electrify both positively, and the following observations may be made: 1. That what is attracted or repelled by the one, is also attracted and repelled by the other; whereas, in the foregoing instance, what the one attracted, the other repelled. 2. That no sparks will pass between two conductors equally electrified with the same power, though they will pass continually between two electrified with different powers. 3. Connect the two conductors that are before the cylinder, and sparks may be taken from them, which cannot be done from the others when they are united.

EXPERIMENT XIII. Take a glass tube, and by drawing the hand with a piece of flannel over the surface, the tube will soon be electrified. The matter leaving the hand passes to the glass, where it remains as an addition to its natural quantity: for, as neither the glass nor the air are conductors, the redundancy of the electric fluid cannot escape till some non-electric body approaches it. If a piece of metal or the hand be presented to any part of the tube, the fluid will pass to the metal with a crackling noise.

But, if the person that rubs the tube be insulated, another person standing on the floor, on applying his knuckle from one end to the other of the excited tube, will get a few sparks from it, but no more, as it cannot get a fresh supply from the earth.

Experiment xiv. *shewing that electrical appearances are produced both in the electric which is excited, and the substance by which it is excited, provided that substance be insulated; but their electric powers are directly reverse of each other, and may be distinguished by opposite effects.*

First, with a machine with an insulated rubber, but no conductor connected with it.

Put the machine in action, connect the cushion by a chain with the ground, and on turning the machine the conductor will be electrified, will attract and repel light bodies, and exhibit the usual electric appearances. Take the chain from the rubber, and suspend it to the conductor, and the cushion will now attract and repel light substances, and exhibit the same general appearances with the prime conductor. If the cylinder be turned while the chain is suspended from the prime conductor to the ground, or any blunt body to the knob at the back of the cushion, so that sparks may pass between it and his knuckle, he is then said to receive negative sparks.

But, if the chain be taken from the prime conductor, and suspended from the knob of the cushion, and a person present his knuckle within the striking distance of the prime conductor, he will receive what are called positive sparks.

The senses cannot determine the direction in which the electric matter moves, but the general opinion is, that, in a common electrical machine, it passes from the cylinder to the points of the conductor; and as the cylinder, as you have seen, affords very little electricity when the rubber is insulated, it follows, that it receives its electricity from the rubber; for, unless the rubber be at liberty to receive an equal quantity from the earth, that is, unless it be uninsulated, it can part but with a small quantity to the cylinder. On this supposition, it is taken for granted by many, that the rubber, when insulated, must lose a part of its natural quantity by friction with the cylinder, and consequently, a conductor communicating with it must be negatively electrified; and that the cylinder, at the same instant that it imparts the electric matter to one conductor, exhausts an equal quantity from the other which is connected with the rubber.

Experiment xv. *Another method of proving that the electric fluid comes from the earth.* Let one person stand on a glass stool, or be insulated, and rub a glass tube, and let another person on a glass stool take the fire from the first, they will both of them, provided they do not stand so near as to touch each other, appear to be electrified to a person standing on the floor; that is, he will perceive a spark on approaching either of them with his knuckle.

2. But, if the insulated persons touch one another during the excitation of the tube, neither of them will appear to be electrified.

3. If they touch one another after exciting the tube, and draw the fire as aforesaid, there will be a stronger spark between them than was between either of them and the person on the floor.

4. After such a strong spark neither of them discovers any electricity.

These appearances may be thus accounted for: the electric fire is a common element, of which each of the three persons has his equal share before any operation is begun with the tube.

A, who stands upon the stool and rubs the tube, collects the electrical fire from himself into the glass, and his communication with the common stock being cut off by the glass of the stool, his body is not again immediately supplied.

B, who is also insulated, passing his knuckle along the tube, receives the fire which was collected from A, and being insulated, he retains this additional quantity.

To C both appear electrified; for he, having only the middle quantity of electrical fire, receives a spark on approaching B, who has an over quantity, but gives one to A, who has an under quantity.

If A and B approach to touch each other, the spark is stronger, because the difference between them is greater. After this touch, there is no spark between either of them and C, because the electrical fluid in all is reduced to the original equality. If they touch while electrifying, the equality is never destroyed, the fire is only circulating.

On the foregoing experiments are founded the present theories of electricity, only two of which will be noticed in this work, that of Dr. *Franklin*, and that of Mr. *Eeles*, as modified by Mr. *Atwood*.

OF DR. FRANKLIN'S HYPOTHESIS.

This hypothesis depends on, and may be reduced to the following principles.

1. That the atmosphere and all terrestrial substances are full of the electric fluid.

2. That the operations of electricity depend on the uncompounded action of a simple fluid of a peculiar nature, extremely subtile and elastic.

3. Glass and other electric substances, though they contain a great deal of electric matter, are nevertheless impermeable to this fluid.

4. That the electric matter violently repels itself, and attracts all other matter.

5. By the excitation of an electric the equilibrium of the contained fluid is broken; and one part becomes overloaded with electricity, while the other contains too little.

6. Conducting substances are permeable to the electric matter through their whole substance.

7. Positive electricity is when a body has more than its natural state of the electric fluid; and negative electricity, when it has less than its natural share, as has been before observed.

The first position, *that all terrestrial substances, as well as the atmosphere, are full of the electric fluid*, is easily proved. For there is no place of the earth or sea where the electric fluid may not be collected, by making a connexion between the place and the rubber of an electric machine. The most conclusive proofs of this position are obtained by the use of *Bennet*'s electrometer and doubler, *plate* 1, *fig*. 10. The case is equally clear with respect to the atmosphere from which the electric fluid may at any time be collected.

The second position does not seem to be well founded; there are many reasons for supposing the electric matter to be a compound substance capable of being separated: at any rate, the position is without proof; for we have no experiments from which it can be fairly deduced, that the electric matter is a single fluid *sui generis*.

The third position for establishing the Franklinian theory is, *that glass and other electric substances, though they contain a great deal of the electric matter, are impermeable by it.* This assertion has evidently a very contradictory appearance. It is very difficult, if not impossible, to conceive that any substance can be very full of a fluid, and yet impermeable by that fluid; especially when we talk of throwing in an additional quantity on one side, and taking out as much from the opposite side.

The only arguments for the impermeability of glass by the electric fluid are drawn from the phenomena of the Leyden phial. It appears indeed, in this case, that there is an expulsion of fire from the outside, at the same time that it is thrown upon the inside. In this experiment, an unphilosophical observer, concluding from appearances, would judge that the fluid passed through the glass. Dr. *Franklin* concludes that it does not pass through, because there is found a very great accumulation of electric matter on the inside of the glass, which is discoverable by a violent flash and explosion between the inside and outside coatings.

But this is mere begging the question, for there is no reason to conclude the glass impermeable, unless you allow the accumulation on one side, and the deficiency on the other. If this supposition cannot be proved, the evidence of sense in favour of the permeability must preponderate.

It is said, indeed, that if the glass was permeable by the electric fluid, a phial would not retain any charge; because the fluid would no sooner be thrown on one side, than it would fly off from the other. This conclusion depends entirely on the foregoing supposition, a supposition which is incapable of proof; namely, that there is an accumulation on one side of the electric, and a deficiency on the other.

Proofs of the permeability of glass will be found in various parts of this work.

The next position to be considered is this, *that the electric matter violently repels itself, and attracts all other matter.* The proofs of this position, like the foregoing, are built on a supposition, which if denied, the proofs fall to the ground. Let a smooth piece of metal be insulated, and bring an excited glass tube near one end of it, a spark of positive electricity will be obtained from the other end; after which, if the tube be suddenly removed, it becomes negatively electrified. Here then, it is said, is a plain repulsion of one part of the electric fluid by another. That contained in the tube repels the fluid in the nearest end of the metal; of consequence, it is accumulated in the other end: and when the tube is removed, the metal is found to be deprived of a part of its natural state of electricity, or is electrified negatively.

It is obvious to remark, before such conclusion can be drawn from this and similar experiments, that it is necessary to prove that positive electricity consists in an accumulation, and negative electricity in a deficiency of electric fluid.

Another argument is, however, drawn from the appearance of the electric fluid issuing from a point, or from any body highly electrified. In the open air this diverges excessively, and the particles seem to be violently repulsive of each other; that they are not so, is plain from the appearance they assume in *vacuo*, when, the resistance of the atmosphere being taken off, the electric repulsion would be more at liberty to exercise itself.

If the electric matter was really elastic, or endowed with a power repulsive of itself, it is impossible it should pass in an uninterrupted column through an exhausted receiver, which however it does, and exhibits no repulsive tendency.

The fifth position depends on the nature of excitation, a subject which is yet very imperfectly understood; too much so to deduce conclusions.

The sixth position seems proved by a variety of experiments; the electric fluid indeed often passes over, rather than through the substance; but neither can it be doubted that it often enters the substance, as in the melting of wires.

The last position on which Dr. *Franklin*'s theory depends, and which may be called the foundation of the whole, is, *that positive electricity is an accumulation, or too great a quantity of electric matter contained in a body*; *and negative electricity is when there is too little.* Of this, however, there is not one solid proof; and all attempts that have been hitherto made to prove it, are only arguments in a circle, or proving the thing by itself, and therefore no conclusion can be made from them. Thus, for instance, a body electrified positively attracts one that is electrified negatively; because the first has too much, and the other too little electricity. But how do we know that the one has too much, and the other too little electricity? Because they attract each other!!! Again, when a phial is electrified positively, there is a constant stream of fire from the outside coating, as there is from the conductor to the inside coating; therefore it is said the outside has too little, and the inside too much electricity. But how is this known to be the case? Because glass is impermeable to electricity! And how is glass known to be thus impermeable? Because one side has too much, the other too little electricity!

We have before observed, that the impermeability of glass to the electric power is a supposition merely hypothetical: there is not a single determinate experiment to prove it; and some of the warmest advocates, as Dr. *Priestley* and *Cavallo*, own that some glass may be permeable. So contradictory is their evidence, that you may gather from it that the *best vitrified* and the *worst vitrified*, *cold* and *warm* glass, are all *more or less permeable.*

You will, in another part of this work, see a proof of their inconsistency, in endeavouring to prove that charged glass has always one surface in a positive, the other in a negative state.

Dr. *Gray* asserts that Dr. *Franklin*'s reasoning, both on the charge and discharge of a jar, is erroneous: see his remarks in the chapter on the Leyden phial. If Dr. *Gray* had considered Mr. *Eeles*'s system, it is probable that his ideas on this subject would have been much clearer than they at present appear to be.*

Mr. *Brooke* has shewn, what Mr. *Eeles* shewed us long before, contrary to the ideas of the best judges and friends of *Franklin*'s theory, that during the time of charging a jar, both inside and outside have the same kind of electricity, and that the negative electricity does not take place till the turning the machine is discontinued.

* *Lyon*'s Remarks on the Leading Proofs of the Franklinian System.

HYPOTHESES BY EELES, &c.

The following hypothesis is extracted from Mr. *Eeles*'s Philosophical Essays, and the Analysis of a Course of Lectures read at Trinity College, Cambridge, by Mr. *Atwood.*

If the reader will carefully compare this theory with the experiments that have been made on the electric fluid, I think he will, with me, agree that it is more simple than Dr. *Franklin*'s, speaks more strictly the language of experiment, and is much less embarrassed with hypothetical suppositions. It pointed out to the author many phenomena which have not only been considered as wonderful, but which have also much embarrassed the partizans of Dr. *Franklin*'s opinion. There are no known phenomena, but what are more readily accounted for on this system, than on any other at present known. That it is free from difficulty, I do not assert; but I am certainly well founded in affirming, that it has strong claims to philosophical attention, and that nothing would have prevented its having long since obtained a fair hearing, but for that spirit of party and bigotry which is to be found as much among philosophers as among politicians and enthusiasts.

HYPOTHESIS.

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

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

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

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

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

6. Electric substances are impervious to the two electricities.

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

I shall now give a few of Mr. *Atwood*'s experiments, and then proceed to Mr. *Eeles*'s own experiments and reasoning. It is to be observed, that Mr. *Eeles* is a very immethodical writer, yet his matter is so good, that no electrician should neglect to read his essays.

Experiment xvi. Electrified bodies attract bodies not electrified, though a thin electric be placed between them.

Experiment xvii. Bodies electrified with contrary powers attract each other strongly, although an electric plate be interposed between them.

Thus flame will communicate heat through substances which are impervious to the flame itself.

Experiment xviii. If one surface of an electric plate be electrified with either power, the opposite surface is electrified with the contrary power, if it be not insulated.

Either power being applied to one of the surfaces, attracts the contrary power through the substance of the electric, and repels the electricity of the same sort with itself.

The two powers being brought to the opposite surface of the plate which is impervious to them, remain suspended, strongly attracting each other, till the interposed plate is broken by their force, or a communication is formed between the two surfaces by some conducting substance.

The union of the two electricities destroys the effects of each other, and leaves the plate discharged.

If either surface of a charged plate communicate with the earth, the power on the opposite surface will expand itself into a conductor which is contiguous to it, although the conductor be insulated.

EXPERIMENT XIX. Let one surface of a charged plate be insulated; although the other communicates with the earth, no discharge of either surface will follow.

EXPERIMENT XX. *rendering the action of the two powers visible.* Let the surfaces of an electric plate be very slightly charged and insulated, and let a circuit with successive interruptions be formed; the two powers will be visible, illuminating the points of the interrupted circuit, and each power will appear to extend further from the surface contiguous to it, the stronger the charge is communicated to the plate; but if the illuminations on each side meet, there will immediately follow an explosion of the whole charge.

The length of the interrupted circuit used by Mr. *Atwood* for this experiment was twelve feet.

EXPERIMENT XXI. *The direction of the two powers visible in a vacuum.* Let an exhausted receiver be made part of the electric circuit, with a charge not sufficient to cause an explosion, and the electricity will appear to proceed in opposite directions from the parts communicating with the vitreous and resinous surfaces.

The direction of the fluid is allowed to be a criterion which will prove or disprove the truth of the Franklinian system. In the two last experiments of Mr. *Atwood*, a double current is evidently visible, and fully contradictory to their system. These experiments receive additional force from Dr. *Gray*'s reasoning, who has shewn the impossibility and absurdity of part of the Franklinian conclusions; and are further confirmed by the following experiment of Mr. *Symmer*, and a similar one by Mr. *Volta*.

When a phial is electrified but a little, Mr. *Symmer* says, that if you touch the coating with a finger of one hand, and at the same time bring a finger of the other hand to the wire, you will receive a pretty smart blow upon the tip of each of the fingers; but the sensation reaches no further. If the phial be electrified a degree higher, you will feel a stronger blow, reaching to the wrists, but no further. When, again, it is electrified in a still higher degree, a severe blow will be received, but will not reach beyond the elbows. Lastly, when the phial is strongly charged, the stroke may be perceived at the wrists and elbows; but the principal blow is felt at the breast, as if a blow from each side met there. This plain and simple experiment obviously suggests the existence of two distinct powers in contrary directions, and perfectly accords with those of Mr. *Atwood*; and is in direct contradiction to that assertion of the Franklinians, that the same quantity of electric matter which is thrown upon one of the surfaces of glass in the operation of charging is driven from the other, and that, in the discharge, the same quantity returns from the one surface to the other.

Mr. *Volta*, in the following argument and experiment, fairly gives up the foregoing position, and endeavours to accommodate his experiment to an hypothesis that it directly disproves.

The subsequent account is extracted from a very long paper of Mr. *Volta*, in the Journal de Physique for 1779.

Let us suppose that *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *k*, *l*, *m*, *n*, *o*, hold hands; let *a* grasp the outside of a charged Leyden phial, and *o* touch the knob; at the instant *o* receives the fire discharged from the inside of the knob, *a* will furnish from his natural stock to the outside, without waiting till the fire arrives to him from *o*, by *n*, to *m*, &c. in the mean while the loss of *a* is compensated from *b*, and *b* is furnished with fresh matter from *c*, and so on. It is still true, that there is but one stream, if we consider only the direction of the fluid, which is excited simultaneously at the two extremities, and moves at the same instant of time; though, to speak more accurately, it is not one stream, but two united in one. If the extreme rapidity with which the fire passes did not prevent our perceiving the successive commotions received by the persons who form the chain, we should find they did not follow the order *o*, *n*, *m*, *l*, but were felt simultaneously, first at the two extremities, *o* and *a*, then at *n* and *b*, *m* and *c*, &c. advancing towards the middle of the chain. Agreeable to this, if the jar is small, the longer the circuit is made, those who are furthest from the extremities find the shock weaker.

To render this account more clear, separate the circuit, and form on a dry floor two rows, *a*, *b*, *c*, *d*,—*e*, *f*, *g*, *h*, interrupted in the middle; let *e* grasp the jar by the outside, and *a* excite the discharge by touching the knob of the jar; now, if the electric fire was obliged to take the shortest course to come to the exterior and negative surface, it ought to descend to the feet of *e*, pass over the boards to the feet of *d*, and then through him to the outside, without acting on *f*, *g*, *h*, which would be out of its circuit. But, contrary to this, the fluid goes out of the direct course to follow that of the conducting persons, which afford it a proper receptacle, and comes to the outside by another source. The fire which goes from the inside from *e* to *f*, *g*, *h*, gives them a sensible sensation in their hands and their heels, shewing itself by a spark, if the hands and the feet are separated a little from each other, and finishes by dissipating itself in the common reservoir. In the same manner *d*, who first gave the fire to the outside, receives it successively from *c*, *b*, *a*, who all draw it in from the floor. The stream, therefore, which proceeds from the knob of the jar, passing through the conducting substance, loses itself in the general source; while, from the same source a sufficient quantity is taken to supply the deficiency of the exterior surface.

If *f*, *g*, *h*, do not form a chain, but are irregularly placed round *e*, the positive part of the fluid may be seen to spread itself on different sides, and divide itself in different branches to reach the floor. The fluid will, in the same manner, rise from the floor to reach *d*, if *a*, *b*, and *c*, are irregularly placed round him; so that each surface excites its own stream; one that enters the jar, the other proceeding from it. Thus also, in the experiments of Dr. *Watson*, where it has been supposed that the electric fluid has made such amazing circuits through rivers, over fields, &c. the fluid from the inside was dispersed in the river, at the instant that the outside collected, from the same source, supplies for its own deficiency.

It appears also from other experiments, that one side of a charged electric may contain more of one power than is sufficient to balance the contrary power on the other side. For, if a charged jar is insulated, and the discharge is made by a discharger with a glass handle, after the explosion, the discharger, and both sides of the jar, will possess a contrary power to that obtained on the side of the jar which was touched the last before the discharge.

Let us now for a few moments turn ourselves to Mr. *Eeles*, and hear him speak for himself.* The electric matter consists of two distinct elastic mediums, or powers, which equally and strongly attract and condense each other, and are equally attracted by all matter.

Hence, when any body is immerged into an electric atmosphere, this atmosphere not only repels that power of electricity in the body which is of the same kind with itself, but equally attracts the power of a different kind which is in the body; and the two powers are separated in the body, as long as it remains immerged in the electric atmosphere.

It is absurd to suppose, that bodies negatively electrified are deprived of their natural share of electricity, for they are no more deprived of it, than when they are positively electrified; and it is a manifest contradiction, to suppose that bodies will repel each other further, the more they are divested of the power of repulsion. Besides, when a body is electrified negatively, it is impossible for any one, by any effects of that body on another body which is not electrified, to know it is thus

* Extracted from "Philosophical Essays," in several letters to the Royal Society, by *Henry Eeles*, Esq.

electrified; unless by bringing a light substance electrified with a known power, to try whether it will be attracted or repelled.

With respect to the Leyden phial, when the jar is charged, it is equally electrified on both sides, but with the different powers of electricity; and when a communication is made by a conductor, the increased power without flies in, and the increased power within flies out; for these powers strongly attract and condense each other when in equilibrium, or in their natural state, and therefore do not in that state exhibit any sensible action.

Glass may be equally electrified on both sides, with either the resinous or vitreous power: the Leyden phial insulated may be charged with either of the powers on the inside, and the other power on the outside, by only immerging it in the atmosphere of a body electrified with either of those powers; and may be discharged and recharged in different order, without contact or communication with any thing but that atmosphere.

Glass is not impervious to the electric powers, for with excited glass, or wax, you may electrify a body through glass with either power.

Experiment xxii. Take a piece of bog-down,* suspend it by silk; then take a pane of

* Mr. *Eeles* used bog-down, which, I am informed, is much more sensible than threads with a pith ball.

clean sash glass and warm it, and let the down hang to the side of it; then bring an excited electric to the other side of the glass, and the down will fly off perfectly electrified, in the same manner as if the glass had not intervened.

If the excited electric be glass, the down will be electrified with the vitreous power; and if wax, with the resinous power. Dr. *Franklin* says, they are different powers thrown from the opposite side of the glass: to do this, he must allow two different distinct powers to exist in all glass, which oversets his whole doctrine.

Dr. *Franklin* also asserts, that glass cannot receive electricity on one side, without parting with an equal portion of its natural share on the other side. But in this he is entirely mistaken, for you cannot electrify a pane of glass on one side, but the other side will be equally electrified with the same power; except you form a communication from one side of the glass with the non-electrics, while you electrify the other side; and then, be your excited electric either resinous or vitreous, it will repel the power of the same kind from the glass, and attract the contrary power from the non-electrics.

Experiment xxiii. Set a Leyden phial on a clear dry electric stand, so that a different power from that you attempt to charge it with cannot be drawn up to the outside, and both sides will be electrified with the same power, whether vitreous or resinous.

Experiment xxiv. *To electrify a pane of glass equally on both sides, either with the resinous or vitreous powers, and that by the atmosphere of a conductor electrified by either of the powers.* Pass ten strong knitting needles through a stick, so that they may lie parallel to, and within half an inch of each other; if they are pointed, the purpose will be better answered; then fix a wax or glass handle to your stick.

When the conductor is electrified, bring the pane of glass near it, and draw the points of the wires which are nearest the conductor a few times slowly over the glass, beginning at the side of the glass next the conductor, and drawing them from the conductor; and you will find this pane of glass electrified equally on both sides, with the power contrary to that of the conductor.

Experiment xxv. *To electrify the glass with the same power as the conductor.* Place one end of the wires near the conductor, and draw your glass under or over the other points that are from the conductor; and the glass will be electrified equally on both sides with the same power as the conductor.

Experiment xxvi. *To electrify a pane of glass equally on both sides, with the vitreous power, by excited wax; and with the resinous, by excited* *glass.* Take a clean, dry, warm pane of glass; place a small bundle of linen rags, suspended by silk, or a sheet or two of paper folded like a letter, or any non-electric, on the glass; bring an excited tube under the pane, and in contact with, or very near it; and when it has remained three or four seconds, toss off the rags or papers, and instantly withdraw the tube; and you will find the pane of glass electrified on both sides with the vitreous power, and the non-electric which was on the pane; with a contrary power.

To explain these phenomena. The two contrary powers of electricity are equally adhesive to the pane of glass, as they are indeed to all matter: they attract and condense each other into almost an insensible space, and do not in that state exert any sensible action;* but the atmosphere of the non-electric drives part of the same power out of the glass into the non-electric; and at the same time attracts the contrary power of electricity into the glass.

Now, the non-electric being taken away, the different powers in the glass are rendered unequal

* This position is illustrated by all the experiments when there is any solution of continuity, as in breaking a stick of sealing-wax, as in the electrophorus, condenser, doubler, &c. which on the other hypothesis are very obscurely explained, if explained at all. Mr. *Wilson*'s experiments with the tubes and pith balls, are also further illustrations of Mr. *Ecles*'s opinions.

to each other; and the increased power, by its elastic force, the attraction of the other power being lessened, expands itself into an extensive atmosphere; which atmosphere acts in all respects like the atmosphere of any electric excited by the same power.

For, all electrics are excited in the same manner, by the separation of the contrary powers, which are equally inherent in them and all other bodies, till separated by friction, &c. And the reason why non-electrics cannot be electrified, unless they are insulated, is, because the different powers change place so quickly; for, the atmosphere of an excited non-electric always attracts one power in the non-electric, and repels the contrary;* yet, as soon as it is removed, the powers instantly unite by their mutual attraction.

EXPERIMENT XXVII. *A Leyden phial being suspended by silk, to charge, discharge, and recharge it with the powers in the contrary order, only by the atmosphere of an electrified conductor.* Fix some sharp pointed wires to the coating of a jar, so that they may project an inch below the coating. Fix some sharp pointed needles, projecting upwards, to the rod in the inside of the jar, suspend the jar by silk, and bring it so that the rod from the inside may point to the conductor. While the

* See this clearly proved by *Wilson*'s Experiments.

wheel is turning, let it remain there for some time, and you will find the inside charged with the same power as the conductor.

Now suspend the jar over the conductor for the same time, with the wires from the bottom pointing to the conductor, and you will find the jar to be discharged. But, let it remain as long again, and the jar will be recharged, but in a contrary order to what it was at first.

The conductor being electrified with the vitreous power, attracts the resinous power from the inside of the jar, and the non-electric contained therein, and enters itself in the room thereof, till the inside is electrified like the conductor with the vitreous power.

The vitreous power on the inside repels the vitreous power on the outside through the points of the wires, and attracts the resinous from the air, till through the points it arrives at the outside of the jar, where it meets a resistance from the glass, and is there held in firm contact by the attraction of the contrary powers on the inside of the jar, and thus the jar remains charged when taken from the atmosphere of the conductor.

When the experiment is reversed, by bringing the wires at the bottom of the jar pointed towards the conductor, the vitreous atmosphere of the conductor attracts the resinous power from the outside, and adds to the vitreous power already there; this power repels the vitreous power from the inside, and attracts the resinous power through the needle, till the jar becomes charged in a contrary order.

The whole of electricity and excitation depends on the separating the vitreous and resinous powers by lessening the one and increasing the other. In excited electrics, these powers are never entirely separate, but the lessened power acts inward to the electric, and the increasing power acts outward from the electric, with an extensive atmosphere.

Mr. *Franklin* asserts, that glass cannot receive electricity on one side, without parting with so much of its natural share on the other side: but this is demonstrably false; for, a pane of glass may be electrified equally on both sides with either power; or the Leyden phial, when insulated, may be electrified at both sides with either power.

M. *Nollet*, when he talked of affluences and effluences, was in a great degree right; but he knew not that it was an affluence of one power and an effluence of another. All his experiments which prove a double current, make directly against the Franklinian system, and in favour of the two powers.

That there is an affluence and effluence, may be proved by many experiments, of which one only will be mentioned here, namely, the common one with the dancing images.

Experiment xxviii. When you dry the head of one of those images, the power thrown out from the conductor cannot enter the image with the same facility with which the contrary power from the table enters at the feet, which are not so dry; this will therefore ascend to the upper plate, and remain there. Reverse the experiment; dry the feet and wet the head, and the image will fix itself to the lower plate. If the image retains so much more of the attracted power as will balance against its weight, than there is of the contrary power which proceeds from the conductor, the image will be suspended between the two plates.

This may be effected by making the head of the image broad and round, which does not admit the power coming out so readily, as the feet, being sharp, admit the power going in. A minute alteration will make the images dance, or remain fixed to one of the plates.

It is not bare matter that is attracted in these experiments, but the electric power which is inherent or adhesive to that matter.

Experiment xxix. *To shew that the electric powers condense each other.* Take two panes of clean sash glass that will lie evenly on each other; place a sheet of paper folded like a letter on your table, place the two panes on the paper, and a like paper on the upper pane; then take a large excited glass tube, and roll your tube over the upper paper; repeat the exciting and rolling five or six times; at the last rolling, take up your panes, upper paper, and tube together, and then immediately take off the tube and upper paper; then bring the two panes joined together to a piece of bog-down suspended by silk, and you will find the panes thus joined have very little effect on the down.

Separate the panes, and each pane will be strongly electrified, the upper pane with the vitreous power on both sides, the under one with the resinous power on both sides; touch the down with either pane, and it will be repelled by that and attracted by the other.

Place your panes together as at first, and then you will find that the powers condense each other, so as to have very little effect on the down; but, as you separate the panes, you will find the different powers act as before.

The panes, if they lie in contact with each other, and are highly electrified, will stick together by their mutual attraction, and separate with a snap.

If the experiment be made on a pewter plate placed on a glass stand, you will find the powers have changed place through the whole; the vitreous power of the tube attracting part of the resinous power from the first glass, and adding part of its own vitreous power to the glass; by which means the glass becomes electrified with vitreous power, which repels the vitreous power of the paper and plate into the under glass; and thus the under glass is electrified with the resinous, and the plate with the vitreous power.

A due consideration of the foregoing experiments will explain all the transactions of the electric powers. For, in exciting, the rubber always draws off as much of one power as it adds of the other; and is, therefore, always electrified with a power contrary to the increased power of the excited electric.

When an excited electric electrifies an insulated non-electric, it draws as much of one power from it as it gives of the other, and is therefore as much unelectrified itself as it electrifies the non-electric; and thus this change goes on, till the powers become equal to each other, which in non-electrics is done almost instantaneously.

Experiment xxx. Place a charged jar upon an electric stand, and let a cork ball suspended by a silk hang against the outside of the jar; touch the top of the jar, and the ball flies off strongly electrified with the resinous power; and thus you may go on for a great number of times, to alter the balance withinside and withoutside the jar, by alternately touching the top and bottom.

Now, can any Franklinian suppose, that it is the return of their positive power to the emptied side of the glass that electrifies the down negatively?

The truth is, when you touch the top, you take a spark of the vitreous power from the inside, and in exchange give as much of the resinous thereto, which lessens the attraction of the vitreous power on the inside, and leaves the resinous power withoutside in greater quantity than the vitreous on the inside, and consequently at liberty to exchange powers with any non-electric in contact with it; and thus the ball becomes electrified with the resinous power.

Experiment xxxi. Take two sheets of paper folded like large letters, and place them on your table, with a pane of clean dry glass on each paper; then take a large glass tube well excited, and roll it over one of the panes; then take up the pane and tube together, and instantly withdraw the tube, you will find that pane strongly electrified at both sides with the resinous power, which Dr. *Franklin* says is a thing that cannot be done.

Repeat the operation, and while your pane is electrified with the resinous power, lay it on the other pane for four or five seconds; take up your panes together, and then separate them: you will find the first pane still electrified with the resinous, or minus power, and the other pane electrified on both sides with the vitreous or plus power.

Now, if any man, says Mr. *Eeles*, can frame or shew an hypothesis, to explain by the action of one single power how a body divested of its natural share of that power, can give another body an additional share of that power, he will overset all the rules of reasoning with which I am acquainted.

It is readily explained on the principle of two powers. The first pane having a greater quantity of the resinous power, repels the resinous power from the second pane to the non-electric under it, and attracts an equal quantity of the vitreous power from the non-electric into the pane; by which means that pane has an increased share of the vitreous power; which increased power will, by its own elastic force, expand into an atmosphere, and therefore the pane will be electrified by that power.

EXPERIMENT XXXII. *for the further illustration of the reciprocal exchange of the electric powers.* Fix a wire to the under part of a coated jar, so that the point may stand upright, and on that point place the needle with the reversed points.

Place this jar on an electric stand, with a communication from the conductor. All the time the jar is charging, the needle will turn; but when the jar is charged, the needle stops. Then touch the top of the bottle with your finger, or any conductor, and the needle will turn till the jar is discharged. Now, while the jar is charging, if you touch the needle with a piece of bog-down suspended by silk, you will find it electrified with the vitreous power, which flies off in exchange for the resinous power drawn in from the air to the outside of the jar; and, while the jar is discharging, if you touch the down in the same manner to the needle, you will find it electrified with the resinous power, which flies off from the outside of the jar in exchange for the vitreous power drawn in through the points from the air; while the vitreous power from the inside of the jar makes the same exchange for the resinous power through your finger, to make these different powers equal to each other, withinside and withoutside the jar.

Experiment xxxiii. Place two Leyden jars on an electric stand, with their coatings in contact; and while you charge one from the conductor, let a person on the floor touch the top of the other jar with his finger; you will find the first jar charged with the vitreous power inside, and the second with the resinous power inside.

Now the exchange here is evident; for, while the resinous power from the inside of the first jar changes place with the vitreous thrown in from the conductor, the vitreous from the coating changes place for so much of the resinous from the coating of the second jar; and the vitreous in that jar changes place for so much of the resinous power drawn in through the man on the floor.

I could easily, says Mr. *Eeles*, furnish experiments sufficient to fill a great deal of paper; but I shall only mention one or two, which I have often made, and have shewn to many gentlemen versed in this science, which perhaps may puzzle the writers on this subject: but whoever can make them, must and will understand my doctrine of electricity; and plainly discover, that all that has been said about positive and negative electricity, or a plus and minus of the same power, has been to little purpose, and only served to keep men in the dark about this science.

Mr. *Eeles* had a glass globe, entirely smooth, which, with the same rubber, he could make throw out the resinous or vitreous power, and electrify other matters with each power as often as he pleased: and generally he could charge these powers in one revolution of the globe; but in two or three revolutions he never failed to do it.

He had another glass globe entirely smooth, supported by one glass neck, from the equatorial line of which globe he could electrify with the resinous or vitreous power, as he thought proper, without applying a hand or any rubber to the globe, or any friction from the things to be electrified; and what is more, he could electrify two things with the different powers at the same time.

He hopes his readers will forgive him for not explaining these experiments, till he sees who can make them, and explain them by the doctrine of positive and negative electricity, or a plus and minus of the same power.

As he has seen Mr. *Priestley* quoted, for improving and methodizing the theories of M. *du Fay* and Mr. *Symmer*; he observes, that M. *du Fay* never thought of the co-existence of these different powers in all bodies; nor even Mr. *Muschenbroeck*, long after him; therefore, there was not any theory of M. *du Fay*'s to be methodized. His papers will appear to have been written to the Royal Society, before Mr. *Symmer* thought any thing of the matter; however, as far as he has gone, he was right; and he thinks that Mr. *Priestley* has made too much of a trifling objection to what Mr. *Symmer* has said, that any man from his own sensations, would be convinced that the powers came in opposition from both sides of the jar, by feeling a slight shock in his wrists, a stronger in his elbows, and so on; Mr. *Symmer* did not say that these powers did not circulate through the body, but that this sensation would shew their different direction; and an explanation of these different sensations depends on a knowledge of anatomy, and the action of these powers on the different parts, which it is possible that both Mr. *Priestley* and Mr. *Symmer* may be strangers to. But this objection was only a pretext to mend Mr. *Symmer*'s discoveries. Mr. *Eeles* believes it will plainly appear to any gentleman, who does him the honour to read his papers with attention, that the only theory which Mr. *Priestley* could have methodized, must be what he took from his papers; if an hypothesis can be said to methodize a doctrine which was clearly proved by experiments ten years before. He pertinently asks, which of Mr. *Priestley*'s own numerous experiments, or what experiments of any other man, he has explained by his hypothesis? or how he has supported this hypothesis? or whence he took it? For he has not produced a single experiment in aid of it, to shew the existence or manner of acting of these different powers. Or he would ask, whether his hypothesis has added any thing to the truth or explanation of what he has written? Or, if he had happened to have written that hypothesis, whether he should have put this matter in a clearer light than what he has done? Or, what man would have depended on that hypothesis, without any other proof? So that he thinks Mr. *Priestley* may fairly own from whence he framed his hypothesis; for, after reading these papers, Mr. *Priestley* has shut Mr. *Eeles* out of his history of electricity; though all his papers were addressed to the Royal Society, of which he is a member; and it appears from the first of them that his attempt, to shew the electric powers were the cause of thunder, was approved by that society; and is the only attempt of that kind which stands recorded in the Philosophical Transactions. As for the rest of them, with Mr. *Priestley* and his hypothesis, he leaves to the judgment of unprejudiced readers.

CHAP. V.

ON THE METHOD OF USING THE ELECTRICAL APPARATUS, AND A DESCRIPTION OF THE PRINCIPAL ARTICLES THEREOF.

MR. *Becket* has well observed, that an electrician should divest himself of fear, though not of caution. There is no possible danger in any electrical experiments, except in the charging of large jars and batteries; nor need he be under any fear from these, while he is careful not to touch any part of the prime conductor, or the wires leading to the insides of the jars.

It is not, however, unusual for persons, who are but little acquainted with the nature of electricity, to testify evident marks of fear, upon their approaching an electrical machine: some can scarce be prevailed on to receive the slightest discharge from the phial, or even to take a spark from the conductor, though they see others perform both without the least inconvenience. This want of resolution might be excusable in women and children, but one cannot help smiling at the timidity of a man who can express any apprehensions at a momentary smart, of a pain which is rather imaginary than real, and can seldom be of half a second's duration.*

Though I have already mentioned the precautions to be used, and the directions to be followed in exciting and using an electrical machine, yet I hope a repetition will not prove unnecessary; the more so, as it is evidently for the interest of the science, that every thing be made as plain and clear, as easy and inviting, as possible to beginners.

When the weather is clear, and the air frosty, the electrical machine will generally work well; but, when the weather is damp, it will be necessary to bring it into a warm room; the cylinder, all the insulating pillars, and the tops of the jars, &c. should be made thoroughly dry.

.6 # Clean the cylinder and wipe the silk, then grease the cylinder, by turning it against a greased leather, till it is uniformly obscured. Turn the cylinder till the silk has wiped off so much of the grease, as to render it semi-transparent.

Put some amalgam on a piece of leather, and spread it well, so that it may be uniformly bright; apply this against the turning cylinder; the friction will immediately increase, and the leather must not be removed until it ceases to become greater.

* *Becket's* Essay on Electricity, p. 15.

If several jars are connected together, among which there is one that is apt to discharge itself sooner than the other jars, the rest of the jars will be discharged with it, although by themselves they may be capable of holding a very great charge.

To discharge a jar, a communication must be formed between the outside and the inside of the jar by a conducting substance. Thus, if you place one hand in connexion with the outside coating of the jar, and touch the ball with the other, the jar will be discharged, and you will receive the shock. To avoid the shock, three kinds of discharging rods have been contrived; one of these, represented in *plate* 2, *fig*. 1, is a semicircular brass wire, furnished with two brass balls, one at each end of the wire. The second is similar in shape, and is called the luminous discharging rod; the brass balls are connected together by a piece of iron chain, which passes through a glass tube; the handle is of wood: in the discharge, luminous brushes are perceived at each juncture of the chain; this effect will not be produced by a brass chain. The third is a jointed discharging rod with a glass handle, *fig*. 2; the legs of this are moveable, and may be set to any given distance by means of the joint at C, which renders it exceedingly convenient in a variety of cases. The extremities of the legs are pointed;

the points enter into the balls, *a*, *b*, which are screwed on the extremities, and from which they may be unscrewed at pleasure; so that either the balls or the points may be used as occasion requires. These three kinds of discharging rods are used in the same manner; that is, to discharge a jar with them, you place one ball of the discharging rod on the external coating of the phial, then bring the other to touch the knob of the wire which communicates with the inside of the jar, when an explosion will take place and the phial will be discharged. It is scarcely necessary to say, that the jointed and luminous dischargers are to be held by their respective handles, and the plain one by the semicircular part of the wire.

Mr. *Brooke* asserts, that the spontaneous discharging of a phial is much facilitated by its being made very dry and clean; insomuch, that a jar will not take so great a charge when quite clean and dry, as it was otherwise capable of being made to take: so that, in order to give the greatest possible charge to a Leyden phial, it seems necessary that something of a very slight oiliness should be rubbed over its surface, something nearly of a non-conducting substance; perhaps a slight coating of tallow. If the electrical apparatus be kept in a very warm dry room, the advantage of soiling the naked part of the glass will soon appear; but, if the apparatus be kept in a cool room, where there is neither fire nor sun, the above-mentioned method will be of little use.

For the purpose of charging batteries or large jars, a large conductor is very disadvantageous; the battery should also be placed at such a distance from the machine and prime conductor, as to be as far as possible from their atmospheres. If the machine and prime conductor be very large, the person who works the machine should be insulated.

Mr. *Brooke* says, that a certain quantity of conducting surface disposed in length, and joined to a prime conductor, added more to the strength and pungency of a spark or stroke, than the same quantity disposed in thickness and joined to the same conductor.*

It is adviseable not to handle a jar or battery, even after it has been discharged, as there is often a considerable residuum: this may be got rid of by applying the discharging rod twice or even thrice to the jar, &c.

To avoid a shock, be careful never to touch the top and bottom of the jar at the same time, nor ever to enter a circuit formed between the inside and outside of a jar.

* See *Brooke*'s Miscellaneous Experiments and Remarks on Electricity, &c.

A charged phial, set upon electric substances, (insulated) may be taken hold of without danger, either by the coating or the wire.

The outside of a charged jar may be handled with impunity. If the knob alone be touched, only a prickling sensation will be felt, the discharge will be silent and without explosion.

If any conducting substance be near the machine while working, it generally receives part of the electric matter, and carries it off: it is therefore proper to remove every thing to a distance that is not immediately wanted. The flame of a candle near the cylinder, or any part of the conductor, effectually takes off the electricity, and spoils the operation.

When the insulating stool, whose feet are of glass, see *plate* 2, *fig.* 8, is made use of, it is very advantageous to place a sheet of clean dry paper under the feet.

When a chain is suspended from the rubber, all bodies in contact with the prime conductor are said to be positively electrified; but, when the chain is suspended from the prime conductor, all bodies in contact with the rubber, or cushion connected with it, are said to be negatively electrified.

A LIST OF THE APPARATUS AS REPRESENTED BY THE FIGURES IN THE PLATES TO THIS WORK, BY THE EDITOR.

It will be of much advantage to the reader, a beginner in the science, to make himself now acquainted with the names of the various apparatus, as represented in the plates to this work, and their places of application. I have enlarged upon the descriptions and the number of references given by our late Author, and placed the references in an orderly arrangement.

PLATE I.

Fig. 1, 2, 3, 4, 5, 6, 7, electrical appearances, as described by Mr. *William Nicholson.*

Fig. 8, a cylinder electrical machine, with a simple winch.

Fig. 9, an electrical doubler, as described by the Rev. Mr. *Bennet* and Mr. *Nicholson.*

Fig. 9, No. 2, a side view of the same instrument.

Fig. 10, Mr. *Bennet*'s gold leaf electrometer, with *Volta*'s condensing plates.

Fig. 11, M. *de Saussure*'s pith ball electrometer.

Fig. 12, the same electrometer placed in a different position.

Fig. 13, a parachute occasionally applied to ditto.

Fig. 14, 15, 16, 17, apparatus for electrical experiments on airs, by *Morgan*, &c.

Fig. 18, Mr. *Bennet*'s apparatus for electrical atmospherical experiments.

Fig. 19, 20, represent experiments with Mr. *Bennet*'s electrometer.

Fig. 21, illustrative of the action of charged jars and atmospheres by Mr. *Bennet*.

Fig. 22, a jar with belt, wire and ball, and cork spider, called the animated spider.

PLATE II.

Fig. 1, a brass semicircular discharging rod, for discharging the electricity of a Leyden jar.

Fig. 2, a jointed ditto. These two have been already described.

Fig. 3, a very useful apparatus, called an universal discharger. A B is the mahogany base, to which are cemented two glass round pillars, C, D; on the top of each of these is also cemented a brass cap, and a double joint, for horizontal and vertical motions; on the top of each joint is a spring tube, which hold the sliding wires and balls, E T, F E; so that these wires may be set at various distances from each other, and turned into any direction; the extremities of the wires are pointed, and are covered occasionally by the two brass balls, which are adapted to the wires by spring sockets. G H is a small round mahogany table, having an ivory slip inlaid in the middle; to this table is connected a round stem fitted into the wooden socket, I: the table may be raised occasionally to various heights, and fixed at any one of them by the screw in the socket, K. The rings shewn at E, F, are for the convenience of a chain or wire being fastened to them.

Fig. 4, is a small mahogany press with a round stem, also fitted to the socket, I, of *fig.* 3: when the table, G H, is removed, this press is to be occasionally substituted. The press consists of two flat pieces of mahogany, and which are forced together by two brass screws, *a*, *a*.

The uses of the table and press are for keeping steady all descriptions of bodies through which the charge of the Leyden jar or battery is to be conveyed.

Fig. 5, is Mr. *Kinnersley*'s electrical air thermometer, and is for shewing the degree of the expansibility of the air within the tube, by different charges of electricity being conveyed through it. a b is a glass tube, on each end of which a brass cap is cemented; c d, a small thermometer tube, open at both ends, which passes through the upper brass cap, and nearly reaches the bottom of the under cap; a box scale, divided into inches and tenths, is fitted to the upper part of the tube. g is a brass wire and ball fixed to the bottom of the under cap: a similar sliding ball and wire, f h, passes air tight through a collar of leathers on the upper cap, and its lower brass ball may be placed at different distances from the ball of the fixed wire, g. The plate of the upper cap is made to unscrew, so that red-coloured water may be put in, previous to the performance of the experiment. By the rising of this water in the thermometer tube over the scale above, the result of the experiment is observed.

Fig. 6, is *Henley*'s quadrant electrometer, generally fitted to a prime conductor, &c. and to point out the relative strengths of the charges of either jars or batteries.

Fig. 7, a brass sliding wire and balls; an useful article to apply to a prime conductor, for conveying the electric fluid to jars, &c. when they may not be of sufficient height or dimensions by themselves, to be contiguous to the conductor.

Fig. 8, an insulated stool with glass legs, for a person to stand on. It is sometimes made large enough to support a chair.

Fig. 9, Mr. *Townsend*'s electrometer, hereafter to be described.

Fig. 10, the repelling feathers; they are to be supported from the conductor by placing into it the wire B A.

Fig. 11, two small pith or cork balls, to be suspended like the above feathers.

Fig. 12, a wire ring, to the circumference of which some small pieces of thread are tied; the projecting piece from the ring fits into the stand, belonging to the plates and stand: z, a wire with a few short pieces of thread fitting into the conductor.

Fig. 13, represents the plates and stand for dancing images. F is a circular plate of brass or copper, to be suspended horizontally from the conductor by a chain or wire; G is a similar, but larger plate, and is to be placed parallel to the former, and is supported by a brass stand I, the upper part of which may be raised or lowered at pleasure.

Fig. 14, the attracted and repelled pieces of gold leaf.

Fig. 15, represents two wires placed parallel to each other, for the same purpose as *fig.* 13; in this way, however, it is rather difficult to make the experiment succeed.

Fig. 16, the brass hoop for revolving glass balls.

Fig. 17, a set of musical bells and clappers: no experiment illustrates better the general principles of electricity than this small apparatus. V Y, a wire to which the bells are attached; R S, a bent wire, to suspend them from the conductor; the two outer bells are connected to the wire, V Y, by chains; but the middle bell, and small clappers between the bells, are suspended by silk threads. From the concave part of the middle bell, a brass chain, X, proceeds, designed to fall upon the table; a piece of silk thread should be tied to the extremity of this chain.

Fig. 18, represents a more elegant form of mounting the bells. The pillar, A, is of glass; the cross on the top thereof is of brass; the four outer bells are affixed to this by wires or chains; the clappers are suspended on silk threads from the cross; the middle bell communicates with the ground by the foot. To use these, the knob, a, must be in contact with the conductor.

Fig. 19, a set of eight musical bells, or the gamut. In these, the clapper is suspended from the fly, b c d; the axis of the fly rests in a small hole, on the top of the glass pillar e f, in which it turns with great freedom: bells of different tones are placed round the board, h i k.

To use these bells, remove the prime conductor, and place the bells so that the fly may be near the cylinder; when the electric fluid has put the fly into motion, it will cause it to turn round, the clapper will strike each bell in rotation, and thus produce a pleasing and harmonious effect.

Fig. 20, a small bundle of threads tied together at each end.

Fig. 21, an electrified glass tumbler, representing the motions of pith balls by attraction and repulsion.

Fig. 22, 23, 24, 25, 26, 27, small cylinders of wood and brass tubes on insulating glass stands, furnished with pith balls; four tubes, two of wood and two of brass, and stands, are generally sufficient. The experiments with this little apparatus are interesting and instructive.

PLATE III.

Fig. 28, a glass rod six feet long, with six pair of pith balls suspended on it.

Fig. 29, a large metallic conductor, A; with the brass sliding ball C, &c. for taking the most powerful sparks from the conductor.

Fig. 30, represents the electric spark from the conductor, as issuing in a divided state into parts.

Fig. 31, the spiral tube, composed of two glass tubes, one within the other, and closed with two knobbed caps of brass. The innermost tube has a spiral row of small pieces of tin-foil fixed upon its outside surface, and laying at a small distance from each other. It is to be held by one end; the other end is to be presented so as to take sparks from the prime conductor, which will be seen in a pleasing manner at all the interstices between the spots of tin-foil.

Small round pieces of tin-foil are sometimes fixed on flat pieces of glass disposed into various figures, one side of the glass is painted with different transparent colours; the spark seen through these appears of the colour through which it is seen.

Fig. 32, a luminous word acting upon the same principles; the word is formed by small separations made in the tin-foil; a chain is to be suspended from the hook, h; the ball, G, is to be presented to the conductor, so as to take sparks therefrom.

Fig. 33, a conductor, with ladle, I; shewing the manner in which spirits of wine or inflammable oils may be fired by the electric spark.

Fig. 34, the electrical flyer; it consists of two sharp-pointed wires, joined at the center; the ends of the same wires are bent contrary ways; the center at K is a small concavity, that the flyer may be placed on the pointed end of the wire, L; the wire, L, is to be placed in one of the holes on the top of the conductor; when electrified, the flyer will turn with as much velocity as the flyer of a common jack.

Fig. 35, represents a similar flyer, acting in a different position, the axis being at right angles to the flyer, with two small pullies, one at each end of the axis; the wires, M N, O P, should be insulated, and the inclination to the horizon very small.

Fig. 36, a flyer acting as a crane to raise a small weight.

Fig. 37, a set of flyers.

Fig. 38, the glass bottle and bent neck, s, for making inflammable air.

Fig. 39, the electrical pistol for firing inflammable air. This pistol is to be filled with inflammable air, as described in these Essays; a cork is to be put in the end a c, to prevent the escape of the air.

Fig. 40, represents the part within the pistol, by which the spark passes through and fires the inflammable air.

Fig. 41, a small cap to be taken off when the pistol is in use; under this cap is the brass ball, n, *fig.* 40, which is to receive the spark from the prime conductor.

Fig. 42, 43, 44, 48, 50, 51, 52, 54, 55, 56, 57, represent some of the various experiments which may be performed by the compound apparatus, *fig.* 49.

Fig. 45, represents a jar with moveable coatings: the innermost coatings are to be taken out by the silken strings, f, and the jar then lifted out from the external coating.

Fig. 46, represents what is called the spotted or diamond jar; the outside being coated with little pieces of tin-foil, which are placed at a small distance from each other.

Fig. 47, represents the double jar, one being placed on the top of the other; with this many curious experiments may be performed.

Fig. 49, the articles within the line of this figure constitute what is called the *compound apparatus*; it is certainly a most interesting part of the electrical apparatus, as well from the variety, as importance of the experiments performed with it. As it is particularly described in the course of this Essay, I shall say but little of it here: it consists of two small Leyden phials, H, I, one of them, H, furnished with a brass belt; an exhausted flask, E, which is called the Leyden vacuum; an exhausted tube, C D, termed the luminous conductor; a glass insulating pillar, A, on a foot, B; M, a board, to put occasionally on the top of the pillar; K, L, two wires to screw to different parts of the apparatus.

Fig. 53, the belted jar, designed to prove the direction of the electrical fluid in the charging and discharging of the Leyden phial.

Fig. 58, the musical bells; an interesting apparatus, which affords much amusement, while it illustrates clearly the nature of the Leyden phial.

PLATE IV.

Fig. 59, 60, 61, 62, represent more various experiments which may be performed by the combined apparatus of *fig.* 49, *plate* 3.

Fig. 63, 64, experiments with the universal discharger.

Fig. 65, represents a battery consisting of nine jars.

Fig. 66, an apparatus, by *W. Jones*, for rendering eggs luminous.

Fig. 67, 68, 69, 71, 72, experiments tending to shew the influence of knobs and points in producing an electrical explosion.

Fig. 70, Mr. *Nicholson*'s improvement on *Bennet*'s electrometer, to distinguish the different intensities as shewn by the divergencies of the gold leaf, or the distances at which they strike a pair of uninsulated metallic bars.

Fig. 73, an electrical inflammable-air cannon.

Fig. 74, 75, an electrophorus.

Fig. 76, Mr. *Cavallo*'s atmospherical electrometer.

Fig. 77, a small pail and pipe, for shewing the subdivisions of fluids by electricity.

Fig. 78, a conductor and electrometer connected with the cord of an electrical kite.

Fig. 79, *King*'s electrical orrery, shewing the motions of the sun, earth, and moon.

PLATE V.

Fig. 80, 81, apparatus for atmospherical electricity, contrived by Mr. *Cavallo.*

Fig. 82, an exhausted glass receiver on the air-pump plate, with the appearance of electricity as conveyed by the ball and wire.

Fig. 83, a tube, partly filled with air, quicksilver and ether, for producing a beautiful green spark.

Fig. 84, two glass tubes, L, M, with wires passing through them, for communicating electricity to the ear.

Fig. 85, a Leyden phial, with a medical electrometer fixed to the top of it, and two directors, one connected with the top and the other with the bottom of the jar; the figure represents the manner of passing a shock through the arm.

Fig. 86, a Leyden phial, electrometer, and electrical discharging forceps.

Fig. 87, Mr. *Morgans*'s plan of constructing *Brooke*'s electrometer.

Fig. 88, a tube for throwing fluids on any part of the body.

Fig. 89, is a perspective view of the powder-house, the side and the roof next the eye being omitted, that the inside may be more conveniently seen. The front is fitted up like the thunder-house, F G, *plate* 4, *fig.* 68, and is used in the same manner; the sides of the house, the back, and fore front, are joined to the bottom by hinges; the roof is divided into two parts, which are also fastened by hinges to the sides; the building is kept together by a ridge on the roof; when the roof is blown up, it will fall down with the sides, the back, and fore front. To use this model, fill the small tube, *a*, with gun-powder, and ram the wire, *c*, a small way in the tube; then connect the hook, *e*, with the bottom of a large jar or battery; when the jar is charged, form a communication from the hook, *d*, to the top of the jar; the discharge will fire the powder, and the explosion of the gun-powder will throw off the roof, and the sides, the fore and back fronts, will then all fall down.

Fig. 90, represents a wooden pyramid, designed to shew the experiments which are made with the thunder-house, and is used in the same manner. When the piece, *a*, is thrown out by the discharge, the upper part of the pyramid falls down.

Fig. 91, represents the inflammable air lamp, invented by Mr. *Volta*. A is a glass globe to contain the inflammable air; B, a glass bason or reservoir to hold water; D is a stop-cock, which is to form occasionally a communication between the reservoir of water, B, and that of air, A; the water passes into the latter through the metal pipe, *g g*, which is fixed to the upper part of the reservoir, A; at *s* is a small cock, to cut off or open a communication with the air in the ball and the jet, K.

N is a small pipe to hold a piece of wax taper; L, a brass pillar, on the top of which is a brass ball; *a* is a pillar of glass, furnished at top with a socket; a wire, *b*, slides in this socket, a ball is screwed on the end of the wire. F is a cock, by which the ball, A, is filled with inflammable air, and which afterwards serves to confine the air and the water that falls from the bason, B, into the ball, A.

To use this instrument, after having filled the reservoir, A, with pure inflammable air, and the bason with water, turn the cocks, D and s, and the water which falls from the bason, B, will force out some of the inflammable air, and cause it to pass through the jet, K, into the air. If an electric spark is made to pass from the brass ball, *m*, to the brass ball, *n*, the inflammable jet, which passes through the pipe, K, will be fired. To extinguish the lamp, shut first the cock, s, and then the cock, D.

To fill the reservoir, A, with inflammable air, which is to be made in the usual manner, and with the usual apparatus; having previously filled A with water, place the foot, R, under water, on a board or stool in a large tub of water, that the bent glass tube, through which the inflammable air passes, may pass commodiously under the foot of the lamp: when the air has nearly driven out all the water, turn the cock F, and the apparatus is ready for use. This instrument is convenient to preserve a quantity of inflammable air ready for any occasional experiment, as charging the inflamable-air pistol, &c. It is also convenient to light a candle for economical purposes, as the smallest spark from an electrophorus, or a small bottle, is sufficient to fire the air.*

A small battery of inflammable-air pistols is occasionally made, that affords considerable amusement; as either one pistol, or the whole together, may be fired at the pleasure of the operator.

Fig. 92, represents a small glass tube, stopped at one end with a piece of cork: *k* is a wire which passes through a piece of cork, fitted into the other end of the tube; the upper part of the wire is furnished with a brass ball: the end of the wire within the tube is bent at right angles to the rest of the wire.

Fig. 93, a pair of directors and wooden point.

Fig. 94, a glass tube and wire, for making experiments on the conducting power of water, &c.

Fig. 95, 96, 97, Mr. *Brooke*'s electrometers.

Fig. 98, A set of spiral tubes, being a more brilliant display than shewn by *fig.* 31, *plate* 3.

Fig. 99, a strip of silk, jar, rubbers, &c. to produce an electric charge by friction on a ribbon only.

* See a material improvement in the construction of this curious instrument, and a figure, in my edition of the Author's Lectures on Philosophy, five vols. 8vo. 43 plates, 1799. Edit.

Fig. 100, an hollow glass director, *g*, partly coated to hold a charge, and a solid one, *h*, connected with it, by which small shocks may in some instances be conveniently given.

Fig. 101, 102, electrical appearances from Mr. *Bennet*'s treatise.

Fig. 103, represents a piece of twisted fine iron wire, fixed in a glass jar containing pure oxygene or vital air. An electrical discharge from a jar conveyed to the ball will, at its discharge within from the extremity of the wire to the small brass ball, set the wire into a most beautiful deflagration, making in a darkened room a very brilliant appearance, till the whole of the wire is fused.

Fig. 104, 105, exhibit the method of preparing a dead frog, to shew how muscular motion may be produced therein, by merely touching it with a conducting rod applied to the muscles and to the armour of the nerves, as related by Mr. *Cavallo*.

CHAP. VI.

ENTERTAINING EXPERIMENTS BY THE ATTRACTION AND REPULSION OF LIGHT BODIES, WITH SOME REMARKS ON ELECTRICAL ATTRACTION.

Few philosophical sciences afford so much entertainment as electricity; in it the useful and agreeable are intimately blended; and the philosopher, while he is investigating the abstruse parts, is entertained by the variety and beauty of the experiments, which confirm or disprove the hypothesis he wishes to establish.

Experiment xxxiv. *Expanded feather.* Fix the end, A, of the wire, AB, *plate* 2, *fig.* 10, in the small hole which is at the end of the prime conductor; turn the cylinder, and the feathers, which are connected with the wire by linen threads, will separate from each other; the fibrous and downy parts will become turgid, and expand in a pleasing manner, in a variety of directions.

Present a metallic point, the finger, or any other conducting substance to the feathers, the downy parts thereof will immediately collapse, the divergence of the feathers will cease, and they will approach each other and cling round the non-electric body.

The feathers separate from each other, and tend towards unelectrified bodies, from the effort made by the electricity which is communicated to them to diffuse itself, and the resistance it meets with from the air.

A mutual attraction is exerted between a body that is electrified, and one which is in its natural or unelectrified state; which last, if not large and heavy, will fly through the air to the electrified body, where they remain till they have, by the communication, acquired the same state, when they are repelled. If a conductor which is not insulated be at hand, it will attract the small body thus electrified, and deprive it of its electric state; so that it will be again attracted by the electrified body, and repelled as before; and will continue to pass and repass between the two, till the electric state is entirely destroyed.

EXPERIMENT XXXV. *Cork ball electrometer.* Fix the end C of the wire CD, *plate* 2, *fig.* 11, into the hole at the end of the conductor, put the machine in action, and the two small balls, c, d, will recede from each other. Bring a conducting substance within the sphere of their action, and they will fly towards it; touch the conductor with a non-electric, and they will immediately come together.

The balls do not always diverge so much as might be expected from the action of their atmospheres, because they are influenced by that of the conductor.

The balls or feathers will separate, &c. in the same manner, if they are annexed to a negative conductor.

Experiment xxxvi. *Animated thread.* Present a fine thread towards an electrified conductor; when it is at a proper distance, it will fly towards and stick to the conductor, and convey the electric fluid from it to the hand: remove the thread to a small distance from the conductor, and it will fly backwards and forwards with great velocity, and in a very pleasing manner: present the same thread towards one that hangs from the conductor, they will attract and join each other. Bring a non-electric body, as a brass ball, near these threads, the ball will repel that held by the hand, and attract that which is affixed to the conductor: the upper thread renders the brass ball negative, and therefore goes towards it; while the under thread, which is also negative, is repelled. Let the ball be brought near to the lower part of the under one, and it will be attracted by it. The junction of the threads arises from the effort the electric fluid makes to diffuse itself through them.

Experiment xxxvii. *Radiating threads.* To the edge of the brass hoop, b c d, *plate* 2, *fig.* 12, are fastened, at equal distances from each other, six or seven pieces of thread about four inches long. A wire proceeds from the hoop, which fits into a cavity in the pillar D: z e is a brass wire, to one end of which are fastened several small pieces of thread. Fit the plain end of the wire into the hole at the end of the conductor; place the hoop, b c d, at right angles to the wire, z e, and directly over the threads at the end z; turn the cylinder, and the threads tied to the hoop will be attracted by those which are fastened to the wire, z e, and will point towards each other as so many radii of a circle. The electric fluid passes from the threads of the wire into those of the hoop, and thus occasions the seeming attraction between them.

Place the hoop, b c d, on an insulating stand, and when it is saturated with the electric matter, the threads which are tied to it will be repelled by those of the wire: touch the hoop, and they will be again attracted. If the hand is brought near the threads, they will quit their central direction, and move towards it. The ends of the threads appear luminous in the dark.

EXPERIMENT XXXVIII. *Dancing images.* Suspend the small metal plate F, *plate* 2, *fig.* 13, to the conductor by the hook, H; place the stand, I, directly under it, and the large plate, G, on the top of the stand: the upper part of the stand, I, is moveable, so that the distance of the two plates from each other may be occasionally varied. Lay small paper images, or any other light substances, on the under plate, then put the machine in action, and the light bodies will be attracted and repelled by each plate, and move from one plate to the other with considerable velocity.

The light bodies placed on the under plate become possessed of an electricity which is contrary to that of the upper plate, and are therefore attracted by it, and acquire the same electricity with it; they are then repelled and part with this electricity to the stand, and are again in a proper state to be attracted by the upper plate. That these bodies cannot be attracted by the upper plate, till they have acquired a power contrary to it, or till the equilibrium of the fluid in them is disturbed, will be evident from the following experiment.

Experiment xxxix. Remove the under plate and stand, hold in its stead, by one corner, a pane of glass, which has previously been made very clean and dry; now, as glass does not transmit the two electricities, no contrariety in the electric states of the conductor and the light substances can be occasioned, and therefore no attraction or repulsion is observed.

If a finger is presented to the under side of the glass plate, the light bodies will be attracted and repelled: the cause of this will be seen, when the nature of the Leyden phial is explained.

Mr. *Eeles*,* speaking of this alternate attraction and repulsion, says, they may be agreeably varied, by wetting first the heads of the paper images, and, when these are dry, wetting the feet.

" When you dry the head of one of those images, the power thrown out from the conductor cannot enter the image with the same facility with which the contrary power from the table enters at the feet, which are not so dry; this will therefore ascend to the upper plate and remain there. Reverse the experiment; dry the feet and wet the head, and the images will fix themselves to the lower plate. If the image retains so much more of the attracted power as will balance against its weight, than there is of the contrary power which proceeds from the conductor, the image will be suspended between the two plates.

" This may be effected, by making the head of the image broad and round, which does not admit the power coming out so readily, as the feet, being sharp, admit the power going in; a minute alteration will make the images dance, or remain fixed to one of the plates."

Experiment xl. Place a square piece of leaf brass or silver on the under plate, hold this

* Philosophical Essays. Preface, p. 25.

parallel to the upper one, at about five or six inches from it; turn the machine, and the leaf will then rise up into a vertical situation, and remain between the two plates, without touching either of them. Present a metal point towards the leaf, and it will immediately fall down.

Experiment xli. *Moving leaf.* Place a brass ball at K, *fig.* 14, at the end of the conductor, and when the leaf of brass is suspended between the plate and ball, move the plate round the ball, and the leaf will also move round, without touching either ball or plate.

A glass cylinder is occasionally placed between the two metal plates, F, G, *fig.* 13, to prevent bran, sand, or other light substances, being thrown off.

Experiment xlii. Place two wires directly under and parallel to each other, suspend one from the conductor, let the other communicate with the table: a light image placed between these will, when the conductor is electrified, appear like a kind of electrical rope-dancer. See *fig.* 15.

Experiment xliii. *Electric fish.* Cut a piece of leaf brass, with an obtuse angle at one end and a very acute one at the other; present the large end towards an electrified conductor, and, when the leaf brass is within its atmosphere, let it go; it will then fix itself to the conductor by the apex of its obtuse angle, and, from its continual wavering motion, will appear to be animated.

The next experiment requires considerable attention to make it succeed; as a small difference in the apparatus, or in the force of the machine, &c. will make it fail: when it answers, it generally affords pleasure to, and excites admiration in the spectators.

Experiment xliv. Fix the ring, N O P, *fig.* 16, to the end of the conductor; place the plate G, *fig.* 13, on its stand, I, under it, and at a little distance from it, put a very light hollow glass ball upon the plate, but within the ring: turn the cylinder, and the little ball will describe an orbit about the ring, and turn at the same time about its own axis. The poles of its rotation are nearly at right angles to the plane of its orbit.

Experiment xlv. *Electrical bells. Fig.* 17, represents a small set of bells, the two exterior ones are connected to the wire, V Y, by a brass chain, the middle bell and the clappers are suspended on silk.

Hang the bells on the conductor by the hook R S, let the chain from the middle bell touch the table, turn the cylinder, and the clappers will fly continually from bell to bell, as long as the electricity continues.

The brass chain, which connects the two exterior bells to the conductor, conveys the electric fluid to them, which attracts the clappers; these, when they have received the electric fluid, are repelled by the exterior bell, and attracted by the middle one, on which they deposit their electricity: they are then again attracted and repelled by the outer bells. Hold up by a silk thread the chain, X, which proceeds from the middle bell, and the ringing will cease, because it cannot convey the electric fluid communicated by the clappers to the ground.

Fig. 18 represents a more elegant form of mounting the bells. When this is used, the knob, a, should communicate with the conductor.

Fig. 19 represents another kind. In this, the clapper is suspended from the fly, b c d; the axis of the fly rests in a small hole on the top of the glass pillar, e f; the upper part of the axis moves freely in, and is supported by, a hole in the brass piece, g. Bells of the gamut tones are placed round the board, h i K. Remove the prime conductor, and place this apparatus in its stead near the cylinder: when this is in action, it will cause the fly to turn round, the clapper will strike each bell in rotation, and thus produce a pleasing and harmonious sound.

EXPERIMENT XLVI. Take ten or twelve pieces of thread, each about ten inches long, tie them together at the top and the bottom, as in *fig.* 20, then suspend them from the conductor;

the threads, when electrified, endeavour to recede from each other, and the knot at the bottom rising upwards as the repulsion of the thread increases, will form them into a spheroidal figure.

Experiment xlvii. *Flying feather.* Bring a downy feather, or lock of cotton, near the end of an excited tube, or the knob of a charged Leyden phial: the feather will at first fly towards the tube, but when it is saturated with the electric matter, it will recede from it, and may be driven about the room by the excited tube, till it touches some non-conductor, to which it can impart its electricity. The same side of the feather is always turned towards the tube; because the electricity acquired by the feather is forced, by the action of the tube, to that side which is farthest from it, which is therefore repelled.

It is easy to perceive, from this and the foregoing experiments, that it is not the mere matter which is attracted, but that the different phenomena are occasioned by the state of the electric fluid, in those substances which are influenced by the machine.

Experiment xlviii. *Dancing balls.* Put a pointed brass wire into one of the holes which are at the end of the conductor, hold a glass tumbler over the point, then electrify the conductor, and turn the tumbler round, that the whole interior surface may receive the fluid from the point; place a few small pith of elder, or cork balls on the table, and cover them with this glass tumbler; the balls will immediately begin to leap up and down as if they were animated, and will continue to move for a long time. See *fig.* 21.

This experiment may be agreeably varied with two tumblers. Electrify the inside of one positively, of the other negatively; put the balls in one tumbler, and then bring the mouths of both in contact, the balls will pass from one to the other, till the contrariety between them is destroyed.

CHAP. VII.

THE PROPERTIES OF ELECTRIC ATTRACTION AND REPULSION, ILLUSTRATED BY EXPERIMENTS ON LIGHT BODIES.

NATURAL philosophers were originally incited to consider the nature of electricity from its strong attractive and repulsive powers. The phenomena exhibited by those mysterious properties are so various and so pleasing, that they were led, as by enchantment, to pursue the subject; and have been richly rewarded by the discoveries, which are both interesting and important.

The pow'ers of genius have been exerted with industrious ardour to investigate the causes of those properties; but they are still involved in deep obscurity, and we are still totally ignorant of that mechanism by which light bodies, when electrified, approach to or recede from each other.

To enter into a discussion of the difficulties,* which perplex this subject, would lead me too far

* "Qui pourroit concevoir qu'un corps agit *ou il ne'est pas*; sans aucun intermede? Deux particules de *matiere* sont a cent milles lieures, ou a cent milliemes parties d'un ligne de distance l'un de l'autre, sans aucune communication materielle entrelles, et a l'occasion de l'une l'autre se mouvroit!!" *De Luc*, Lettres Physiques, &c.

from the design of this Essay; I shall, therefore, proceed to state those general properties or modes of action, which are observed in electric attraction and repulsion, and then describe the experiments from which those properties have been deduced, or by which they are illustrated.

GENERAL PROPERTIES OF ELECTRICAL ATTRACTION AND REPULSION.

1. The electric fluid, when in action, disposes or places light bodies in such manner, as will best facilitate its transmission through them, with the greatest velocity; and this in proportion to the gravity of the body, its conducting power, and the state of the air.

2. Bodies that are electrified positively repel each other.

3. Bodies that are electrified negatively repel each other.

4. Bodies electrified by contrary powers attract each other strongly.

5. Bodies that are electrified attract those substances which are not electrified.

6. Those substances that are brought within the influence of electrified bodies, become possessed of a contrary electricity; or, electrified substances, without parting with their own electricity, act upon other bodies in their neighbourhood, producing in them an electricity which is

contrary to their own; or bodies which are immerged in an electric atmosphere, always become possessed of an electricity contrary to that of the body in whose atmosphere they are immerged.

The experiments described in this chapter are simple, easily performed, and certain in their results; and, though they may at first sight appear to be trifling, yet, on an attentive examination, they will be found of considerable importance, as they afford a clue to investigate and explain a variety of electric phenomena, and exhibit, in a strong point of view, some of the contrary effects of negative and positive electricity.

These experiments may all be made with a small and portable apparatus; consisting generally of two small brass tubes or cylinders, as A and B, *plate* 1, *fig.* 22; each of these is supported on a glass pillar G, which screws into a wooden foot H; a pair of small pith balls suspended on linen threads, as I, K, fit upon each tube by means of a small brass ring; these tubes, with a piece of sealing-wax or a glass tube, are sufficient to illustrate the greater part of the experiments in this chapter, as well as some of the principal phenomena in electricity.

The apparatus will be rendered more complete, when it consists of four brass tubes with their stands.

Mr. *Wilson*, in a masterly tract on this subject, entitled, "A Short View of Electricity," has, with a similar apparatus, explained and illustrated all its general principles.

EXPERIMENTS ON THE TWO ELECTRIC POWERS.

EXPERIMENT XLIX. Touch a pair of insulated pith balls with an excited glass tube, they will become electrified, and will separate from each other: the balls are electrified positively, and are therefore attracted by excited wax,* and repelled by excited glass.

As those light substances, which possess the same electric power, repel each other; we can easily discover whether they are electrified positively or negatively, by presenting an excited stick of sealing-wax or glass to them. If they are attracted by the glass, they are negatively, if repelled by it, they are positively electrified: on the contrary, if repelled by the excited wax, they are negative, if attracted, positive.

In ascertaining the nature of the electric powers, we must avoid bringing the bodies to be tried near each other suddenly, or one with a strong electricity near another which is weakly so; as it may render the experiment doubtful, by attracting and not repelling the light body.

* A round stick of sealing-wax, about twelve or fifteen inches long and at least one inch in diameter, is an useful article for producing negative electricity. EDIT.

Experiment l. Hold an excited glass tube over one of the brass tubes, but at some distance from it; part of the natural quantity of electricity contained in the brass tube will be driven into the pith balls that are annexed to it, by the excited glass, the balls will diverge with positive electricity; remove the excited glass, the balls will then return to their natural state, and close.

If the excited glass continues in its place, the balls will continue to be repelled; for the excited electric will always continue to separate the powers of electricity, or, in other words, to force a quantity from the surface of the tube; and will also prevent its return, so long as it continues of the same force, and acts at the same distance.

The nearer the excited electric is brought, the greater is the effect.

The sphere of action of an excited electric has been distinguished into two parts, one termed the *sphere of influence*, in which the balls will separate, but close when the electric is removed; the other is called the *sphere of communication*, in which the force acquired by the balls remains after the excited electric is removed.

Experiment li. Electrify the pith balls that are suspended from the brass tube A, *fig.* 27, then bring the end of this tube in contact with the end of the tube B, the balls of which are unelectrified: the stock of electricity given to the tube, A, will be equally divided between each pair of balls, those of the tube, B, will open, and those of A will close a little.

Experiment lii. Electrify the tubes, A and B, *fig.* 27, equally and with the same power, put the ends of the tubes together, and the divergence of the balls will not be altered.

Experiment liii. Electrify the tubes equally, but with the different powers, one with glass, the other with wax; bring the ends of the tubes in contact, and the balls will close.

We learn from these experiments, that the positive and negative powers counteract each other; whence, if both are applied at the same time to any body, the electricity it acquires will be only the difference of the two, and consequently that of the strongest.

Experiment liv. Hold an excited glass tube to one of the brass tubes, touching this tube at the same time with your finger, part of the natural quantity of the electric fluid resident in it will be forced by the excited glass tube into the finger; remove at the same instant the finger and glass, and the balls will remain negatively electrified.

Experiment lv. Place the brass tubes, A and B, *fig.* 22, in a straight line, with their ends in contact; hold the excited glass over the tube A, part of the electric fluid naturally resident in this will be driven into B: separate the tubes, the balls of A will be negative, and those of B will be in a positive state; bring them together again, and the balls will close.

The tube, A, was in the foregoing experiment electrified with the negative power, B, with the positive; but, when they were brought together, the equilibrium was restored: evincing, that no addition of electric matter was communicated to them, but that the natural powers of electricity resident in the tubes were separated by the atmosphere of the excited electric, and proving the co-existence of the two powers in every substance. For the electric fluid, according to Mr. *Eeles*, consists of two elastic mediums, which equally and strongly attract each other, and are attracted by all other matter. Therefore, when any body is immerged in an electric atmosphere, this atmosphere repels the power which is of the same kind in the body, and equally attracts that which is of a different kind in the same body; and while these bodies remain immerged in this atmosphere, the powers remain separated, different atmospheres existing and acting at each end. But, when the electric is removed, the two powers instantly join, and becoming equal, do not manifest any sensible action.

Experiment lvi. Insulate a long metallic rod, suspend a pair of pith balls from each end of it, place one of the ends at about two inches from the prime conductor, the other end as far from it as possible; electrify the conductor, and the electric fluid in the rod will be driven to that end which is furthest from the conductor: so that one end will be electrified negatively, the other end positively, as will be seen by the balls.

Experiment lvii. Apply a stick of excited wax to the tube D, *fig.* 22, as at A; while it remains there, the balls, I, open with negative electricity; raise the wax, as at B, and the balls will close; raise it still higher, to C, and they will open with positive electricity.

Experiment lviii. Excited glass held over the middle of the tube A, *fig.* 24, forces some part of the natural quantity of electricity of A into the balls, and some part out at the two ends into the air. During this experiment, the balls of A are repelled by glass, and are therefore in a positive state; but, after the excited glass is removed, they in a very little time change to a negative state, because part of the natural quantity had escaped from the pointed ends into the air, while the glass was held over the tube; but, when the glass is removed, the over-charge in the balls will of course return, and diffuse itself equally in the tube: but, as this is not sufficient to balance the loss sustained, the tube, thread, and balls, must be in a negative state.*

* *Wilson's* Short View of Electricity, p. 7.

Experiment lix. Place three tubes, A, B, C, *fig*. 25, in a line near to or in contact with each other; excited glass held over A forces out part of the natural quantity of fluid contained in A, into B and C; separate A from B and C, A will be electrified negatively, B and C will be in a positive state. Put the three tubes into their former situation, the equilibrium will be restored, and the balls will collapse.*

Experiment lx. Place four tubes, as A, B, C, D, *fig*. 26, in contact with each other; excited glass held over A forces part of the fluid contained in it into B, the quantity received in B will force out a certain portion from C into D; the moment before the excited glass is removed from A, separate B and D from A and C, after which it will be found, that A and C are in a negative, and B and D in a positive state.†

Experiment lxi. Excited glass held at about one inch distance from the end, B, of a solid cylinder of glass, B D, *plate* 3, *fig*. 28, which is six feet long, and about half an inch diameter, will force part of the fluid at the end B towards the remote end D; but, in doing this, the natural quantity belonging to the glass will undergo several alterations, which are discovered

* *Wilson's* Short View of Electricity, p. 8.

† Ibid.

by the effect an excited glass tube has on a number of pith balls, which are suspended at equal distances from each other, between B and D; in a little space of time, the electricity of these is changed, those that were positive will become negative, and those that were negative will become positive.

If the excited glass is held in contact with the end B, the additional quantity received at B will, in going towards D, cause several alterations in the density of the fluid in B D: but these alterations will be converse to the former, and, after a little time, will also be reversed.

It may be inferred from these experiments, that whenever the electric fluid in any body becomes suddenly more dense in any one part, the fluid in the neighbouring parts will be more rare, and *vice versa*. These alternate changes of rarity and density must, from the nature of an elastic fluid, continue to oscillate many times backwards and forwards before the fluid can be at rest; though, when these motions are weakened to a certain degree, they are imperceptible to the observer.*

Most of the preceding experiments may be made with cylinders of wood or glass, instead of brass. When glass is used, it must be kept dry and not disturbed by friction.

* *Wilson's* Short View of Electricity, p. 18.

It is not improbable, that the attractive and repulsive motions of electrified bodies are owing to the alternate condensation and dilatation of the electric fluid on the surface of these bodies, as they are naturally carried where they meet with the least resistance.

That there is a vibratory motion or struggle between the electric fluid, when in action, and the air, is evident from that sensation which is felt when a strongly excited electric is brought near any part of the human body; and is such as would be occasioned by a spider's web drawn lightly along the skin. This circumstance is rendered more clear by an experiment made by Dr. *Priestley*, in order to discover whether electricity was concerned in the freezing of water.

Experiment lxii. He placed two dishes with water in the open air in the time of a severe frost, one of them he kept strongly electrified, and could observe no difference in the time when it began to freeze, or in the thickness of the ice when it had been frozen for some time; but he observed on each side of the electrified wire, the same dancing vapour which is seen near the surface of the earth in a hot day, or at any time near a body strongly heated.

An electric substance contained between parallel surfaces, however disposed, is called an *electric plate*.

EXPERIMENT LXIII. Electrified substances will attract those which are not electrified, although a thin electric plate be interposed between them.

EXPERIMENT LXIV. Bodies electrified with contrary powers attract each other strongly, although an electric plate be interposed between them: and, indeed, all those phenomena which depend on the influence of the electric atmospheres may be produced, although an electric is interposed between the body and excited electric.

The above-mentioned experiments shew clearly that electrics are permeable by the separated states of this fluid: these experiments have been introduced before in another part of this work.

To account for any of the phenomena of electric attraction and repulsion, is very difficult; but more so to shew why bodies, which are electrified with the same power, repel each other, particularly those which are negatively electrified. Philosophers have invented various solutions of this difficulty; the following is esteemed the best.

"* To understand why bodies possessed of the same electricity repel each other, the reader must be reminded of the following principle, *viz.* that the electric fluid, proper to a body, can neither be augmented nor diminished on the surface of that

* *Cavallo's* complete Treatise of Electricity, p. 110.

body, except the said surface is contiguous to an electric, which can acquire a contrary electricity at a little distance; from whence it follows; that no electricity can be displayed on the facing surfaces of two bodies, which are sufficiently near each other, and both possessed of the same electricity, because the air that lies between them has no liberty of acquiring a contrary electricity. This being premised, the explanation of electric repulsion becomes easy. Suppose, for instance, that two small bodies are freely suspended by insulated threads, so that, when they are not electrified, they hang contiguous to each other: now suppose these bodies to be electrified positively or negatively, and they must repel each other; for either the increased or diminished quantity of the electric fluid in these bodies will endeavour to diffuse itself equally over every part of the surfaces of these bodies, and this endeavour will cause the bodies to recede from each other, so that a quantity of air may be interposed between their surfaces sufficient to acquire a contrary electricity, at a little distance from the said surfaces; otherwise, if the bodies possessed of the same electricity do not repel each other, so that a sufficient quantity of air may be interposed between their surfaces, the increased quantity of electric fluid, when the bodies are electrified positively, or the remnant of it, when they are electrified negatively, cannot be diffused equally over the surfaces of these bodies; for no electricity can appear upon the surfaces of bodies in contact, or that are very near each other: but the electric fluid, by attracting the particles of matter, endeavours to diffuse itself equally over the surfaces of these bodies, and the bodies are by this endeavour forced ro repel each other."

"* The difficulty is not, however, solved by this theory, which only explains one fact by another, which requires as much explanation as the first: but, overlooking this, it is still insufficient; for, granting that bodies negatively electrified ought to repel each other, till the electricity is equally diffused over their surfaces, yet when this is accomplished, the repulsion ought to cease. Further, there is no reason for supposing the electrification to take place while the bodies are in contact, or nearly so. One may be electrified negatively in one corner of a room, and another in the other. The electrification may also be continued for any length of time we please. So that the electric matter must have diffused itself equally over the surfaces of both. Yet, if we attempt to bring these bodies together, they will repel each other, which ought not to be the case on the preceding supposition."

* Encyclopædia Britannica, p. 2683.

" * Positive electricity has been supposed by another to consist of a vibratory motion in the air and electric fluid, in which the force of the vibration is directed outwards from the electric body: that in negative electricity there is also a vibratory motion, but the force is directed inwards. Now, let us suppose a body positively electrified suspended by a small thread at a distance from any other, the vibratory motion being kept up by an equal pressure on all sides, the body is neither moved to one side nor another; but, when a negatively electrified body is brought near, the force of the vibration being directed outwards in the one, and inwards in the other, the pressure of the fluid in the intermediate space between them is greatly lessened, and consequently the pressure on the other side drives them both together, and they are said to attract each other. If a body electrified positively is brought near the first, the force of the vibrations is directly opposed to each other, and therefore the bodies recede from each other. The case is the same with two bodies negatively electrified: for here the vibration being directed towards both bodies, as towards two centers, must cause them to recede from each other, because if they remained in contact, the vibratory motions would interfere with each other.

* Encyclopædia Britannica, p. 2699.

"When a small body is brought within the sphere of another's electricity, the equable pressure of that vibratory or electrical sphere is somewhat lessened upon the side near which the body is brought, and it is therefore impelled towards the first by the action of the surrounding fluid, in order to keep up the equilibrium. As soon as it arrives there, the vibrations of the fluid around the first body being communicated to that within the pores of the second, it acquires a sphere of electricity as well as the first, and is consequently repelled: the repulsion continues till the vibration ceases, either by the action of the air, or by the body coming in contact with another larger than itself, in which case its electricity is said to be discharged. If, after this discharge, the second body is still within the sphere of the first, it will be immediately attracted, and very soon after repelled; and so on alternately, till the electricity of the former totally ceases."

From several experiments of *Beccaria*'s, it appears that, if the air is thoroughly exhausted from a glass receiver, the attraction and repulsion of electrified light bodies within the receiver grows languid, and soon ceases altogether. This is confirmed by an experiment of Mr. *Cavallo*'s. A pith ball electrometer was suspended within a receiver of an air-pump, by its brass cap; this was then electrified; the balls diverged a little when the air was only rarefied 100 times; when it was rarefied 300 times, the repulsion was scarce discernable; when the rarefaction was greater, they did not diverge at all; and that, whether a small or large quantity of electricity was communicated to the cap.*

EXPERIMENTS ON THE ATTRACTION AND REPULSION OF EXCITED SILK RIBBONS.

EXPERIMENT LXV. Put a black and white ribbon together, and draw them through the fingers; by this operation the white ribbon will be electrified positively, the black negatively, and will consequently attract each other.

EXPERIMENT LXVI. Lay either of the ribbons upon a quire of paper, and draw over it amber, sealing-wax, or any other negative electric, the ribbons will be excited positively.

If positive electrics are drawn over the ribbons, they will be excited negatively.

EXPERIMENT LXVII. A piece of flannel and a black ribbon will excite as well together as a black and white ribbon.

EXPERIMENT LXVIII. Dry two white silk ribbons at the fire, extend them on any smooth plane, draw the edge of a sharp ivory rule over

* Phil. Trans. vol. 73, p. 452.

them; while they continue on the plane they do not seem to have acquired any electricity, yet when taken up separately, they are observed to be negatively electrified, and repel each other.

When they are separated from each other, electric sparks are perceived between them; but, when they are again put on the plane, no light is perceived without a second friction.

Experiment lxix. Place the ribbons on a rough conducting substance, rub them as before, and they will, on their separation, shew contrary electricities, which will also disappear when they are joined together.

If the ribbons are made to repel each other, and then joined together, and placed on the fore-mentioned rough substance, they will in a few minutes be mutually attracted; the uppermost being positively, the undermost negatively electrified.

When two white ribbons receive their friction on a rough surface, they always acquire contrary electricities; the upper one is negatively, the lower one positively electrified.

Experiment lxx. When two ribbons are made to repel each other, draw the point of a needle lengthways down one of them, and they will rush together.

Experiment lxxi. Bring an electrified ribbon near a small insulated metallic plate, it will be attracted but feebly; bring a finger near the plate, a spark will be observed between them, though both together shew no signs of electricity; on the separation of the ribbon, they again appear to be electrified, and a spark is perceived between the plate and the finger.

Experiment lxxii. Lay a number of ribbons of the same colour upon a smooth conducting substance, draw the ivory rule over them, take them up singly, and each will give a spark at the place where it is separated from the other; the last will do the same with the conductor; they are all negatively electrified. Take them from the plate together, they will all cohere in one mass, which is negatively electrified on both sides.

Experiment lxxiii. Let them be placed on a rough conducting substance, and then be separated singly, beginning with the lowermost; sparks appear as before, but all the ribbons will be electrified positively except the uppermost. If they receive the friction upon the rough conductor, and are all taken up at once, all the intermediate ribbons acquire the electricity of the highest or lowest, according as the separation is begun with the highest or the lowest.

The following very curious observations and experiments were made by Mr. *Symmer*. He had been accustomed to wear two pair of silk stockings, a black and a white; when these were pulled off both together, no signs of electricity appeared; but, on pulling off the black ones from the white, he heard a snapping or cracking noise, and in the dark perceived sparks between them. To produce this and the following appearances in great perfection, it was only necessary to draw his hand several times backward and forward over his leg with the stockings upon it.

When the stockings were separated, and held at a distance from each other, both of them appeared to be highly excited; the white stocking positively, the black negatively. While they were kept at a distance from each other, both of them appeared inflated to such a degree, that they exhibited the entire shape of the leg. When two black or two white stockings are held in one hand, they repel one another with considerable force. When a white and black stocking are presented to each other, they are mutually attracted, and rush together, if permitted, with great violence. As they approach, the inflation gradually subsides, and their attraction of foreign objects diminishes, but their attraction of one another increases; when they actually meet, they become flat and joined close together, like so many folds of silk; when separated again, their electric virtue does not seem in the least impaired for having once met. The same appearances will be exhibited by them for a considerable time.

When the stockings were suffered to meet, they stuck together with considerable force; at first Mr. *Symmer* found they required from one to twelve ounces to separate them. Another time they raised seventeen ounces. Getting the black stockings new dyed, and the white ones washed and whitened in the fumes of new sulphur, and then putting them one within the other, with the rough sides together, they required three pounds three ounces to separate them. When the white stocking was put within the black one, so that the outside of the white was contiguous to the inside of the black, they raised nine pounds, wanting a few ounces; when the two rough surfaces were together, they raised fifteen pounds one penny weight and an half.*

* The Rev. Mr. *Lyon* has made many curious experiments on the attraction of ribbons, their cohesion, &c. See *Lyon's* Experiments and Observations on Electricity.

CHAP. VIII.

OF THE ELECTRIC SPARK.

EXPERIMENT LXXIV.

Fix the wire and ball, B, to the end of the conductor, as at A, *plate* 3, *fig.* 29; turn the cylinder, and then bring the knuckle or another metal ball, as C, towards B; if the machine is powerful, a long crooked, brilliant, electric spark, with the appearance of fire, attended with a snapping noise, will pass between the two balls, or between the knuckle and ball.

The experiments in the foregoing chapter shew, that those substances which are brought within the influence of the electrified bodies will become possessed of a contrary electricity, and are consequently in a proper state to receive a spark from any body that is charged with electric matter; and when brought near enough, they will receive the fluid in one explosion. If the conductor is negative, it receives the fluid from the approaching body. The spark does not explode at the greatest distance on a given body, until it has first been made to strike at some smaller distance, which, as it were, entices the discharge gradually forwards.

The longest and most dense sparks proceed from the end of the conductor which is farthest from the cylinder, though long curvilinear sparks may also be taken near the insulating pillar which supports the conductor.

The spark, or quantity of electricity discharged, is nearly in proportion to the size of the conductor; so that larger and longer sparks are obtained from a conductor which has a considerable surface, than from a small one. This has been extended so far, that the force of the spark from a conductor has been equal to a shock from a good sized phial.

The sound is occasioned by the momentary agitation into which the air is thrown by the electric fluid.

If the electric spark is received on any part of the body, it occasions a sensation something resembling a smart blow, which is more or less painful, in proportion to the tenderness of the part, or the strength and weakness of the spark.

When the quantity of electricity is small, and incapable of striking at any considerable distance, the spark appears straight; but when it is strong, and capable of striking at a greater distance, it assumes a crooked or zig-zag direction; and this, probably, because the more fluid electric matter has to pass with great rapidity through the denser and less fluid atmosphere, which reciprocally acts upon each other.

If the uninsulated conducting substance that is presented to the prime conductor, in order to take sparks therefrom, be broad, round, and polished at the end, the sparks will be short and dense, and will produce a considerable sound. If less broad, the spark will be long, crooked, and not so sounding. If the breadth be still more diminished, the conductor begins to come under the denomination of a pointed body; the electric fluid passes to it from the prime conductor, through a great space of air, with a hissing or rustling noise, and in a continual stream. A still greater sharpness enables the electricity to pass over a still greater space, but silently, and nothing is seen but a small light upon the point. If a similar point issue from the prime conductor, and the uninsulated conductor be round and polished, the same effects happen in like situations; but, if both be pointed, the electricity is more readily discharged; and, in all these cases, the appearance of the electric matter at the point of the prime conductor will be that which is peculiar to its electricity—a large divergent cone, if positive; a small globular light or cone, if negative; and the light at the point presented to the prime conductor, will be characteristic of the contrary electricity.

It will be seen, by a great variety of experiments, that the electric fluid is dissipated, unless it is resisted by the pressure of the atmosphere, which keeps the fire together in a body, and by concentrating, it increases its splendor. The spark which explodes in the air is vivid, like lightning; but, if the same is tried in an exhausted receiver, instead of a spark and explosion, we have only a silent, faint, diluted stream.

Beccaria says, that the air resists the electric spark in proportion to its density, and the thickness of the stratum it opposes to the spark, or the length of the passage they open for themselves through its substance. He also shews by a variety of experiments, that the air is driven in every direction by the electric fluid with a force, the action of which does not immediately subside. It will appear from this, as well as many other considerations, that the exceeding great velocity and strength of the electric fluid are not owing to a repulsive power among its particles, but to the mutual action of the air and electric fluid upon themselves and one another; and that its momentum is produced by the incumbent pressure of the atmosphere on the electric fluid, and the pressure of one part of this matter upon another. This latter pressure must be very great, if the particles of the electric fluid are in contact, or act immediately one on the other throughout the wide immensity of space.

The electric spark appears of a different colour, according to its density: when it is rare, it appears of a bluish colour; when more dense, it is purple; when highly condensed, it is clear and white, like the light of the sun.

The middle part of an electric spark often appears diluted, and of a red or violet colour; the ends are more vivid and white, probably because the fluid meets with the greatest resistance at its entrance and exit.

The spark is sometimes divided into many parts, as in *plate* 3, *fig*. 30. The rays of the pencil concentrate where they strike the ball, and form upon it many dense and shining sparks.

EXPERIMENT LXXV. *To render an ivory ball luminous.* Place an ivory ball on the conductor, take a strong spark, or pass the charge of a Leyden jar through the center of it, the ball will appear perfectly luminous. If the charge is not taken through the center, it will pass over and corrode the surface of the ball.

EXPERIMENT LXXVI. *To obtain a crimson coloured spark.* Take a spark through a ball of box wood, and it will appear of a beautiful crimson, or rather a fine scarlet colour; or the shock may be passed through pieces of wood of different thicknesses and density, which will afford a very ample field for observation and experiment.

The two foregoing experiments are so analagous to the famous experiment of Mr. *Hawksbee*, and some others that have been made since his time, that I have subjoined them, and hope they will lead to a further investigation of this curious subject.

EXPERIMENT LXXVII. Mr. *Hawksbee* lined more than half the inside of a glass globe with sealing-wax, he exhausted the globe, and put it in motion; when, on applying his hand to excite it, he saw the shape and figure of it as distinctly on the concave superficies of the wax within, as if only pure glass had intervened between his eye and his hand. The lining of wax, where it was thinnest, would but just allow the light of a candle to be seen through it in the dark. In some parts the wax was at least an eighth part of an inch thick; yet, even in those places, the shape and figure of his hand were as distinguishable as any where else.

Beccaria discharged an electric shock through some brass dust, sprinkled between two plates of sealing-wax; the whole was rendered perfectly luminous and transparent.

EXPERIMENT LXXVIII. *The finger rendered luminous.* This extraordinary experiment was made by Dr. *Priestley*, and is thus described by him. I laid a chain, which was in contact with the outside of a jar, lightly on my finger, and sometimes kept it at a small distance by means of a thin piece of glass. If I made the discharge at the distance of about three inches, the electric fire was visible on the surface of the finger, giving it a sudden concussion, which seemed to make it vibrate to the very bone; and, when it happened to pass on that side of the finger which was opposite to the eye, the whole seemed in the dark perfectly transparent.

Experiment lxxix. *To make a bottle of water luminous.* Connect one end of a chain with the outside of a charged jar, let the other end lie on the table, place the end of another piece of chain at about one quarter of an inch distance from the former, then set a decanter of water on these separated ends; and, on making the discharge through the chain, the water will appear perfectly and beautifully luminous.

Do not these experiments indicate, that there is a subtile medium both in electric and non-electric bodies, that renders them transparent when it is put in motion?

Experiment lxxx. *Green and red sparks.* The sparks taken over a piece of silver leather, appear of a green colour; and over gilt leather, of a red colour.

EXPERIMENT LXXXI. *With the spiral tube.* E F, *plate* 3, *fig*. 31, is a glass tube, round which at small, but equal distances from each other, pieces of tin-foil are pasted in a spiral form, hence it is called the *spiral tube*, from end to end; this tube is inclosed in a larger one, fitted with brass caps at each end, which are connected with the tin-foil of the inner tube. Hold one end in the hand, and apply the other near enough to the prime conductor to take sparks from it, a beautiful and lucid spot will then be seen at each separation of the tin-foil: these multiply, as it were, the sparks taken from the conductor; for, if there was no break in the tin-foil, the electric fire would pass off unperceived.

EXPERIMENT LXXXII. *The luminous word.* This experiment is exactly on the same principles as the foregoing. The word is formed by the small separations made in the tin-foil, which is pasted on a piece of glass that is fixed in a frame of baked wood, as is represented in *fig*. 32. To make the experiment, hold the frame in the hand, and present the ball, G, to the conductor; the spark received on this will be communicated to the tin-foil, and follow it in all its windings, till it arrives at the hook, h, and is conveyed from thence to the ground by a chain. The lucid appearance at each break exhibits a very brilliant word by sparks of fire.

EXPERIMENT LXXXIII. *To take the electric spark with a metal point.* Screw a pointed brass wire into one end of a spiral tube, and present it to the conductor while the machine is in action, when a strong spark will pass between the conductor and the point.

EXPERIMENT LXXXIV. *A strong spark obtained by a point.* Take a clean dry glass tube, of about a quarter of an inch bore, insert a pointed wire in this tube, keep the pointed end at some distance from the end of the tube, let the other end be connected with the ground, bring the former towards the prime conductor, and strong zig-zag sparks, attended with a peculiar noise, will pass between the conductor and the point.

EXPERIMENT LXXXV. *Spiral illumination.* Take a round board well varnished, and lay on it a chain in a spiral form; let the interior end of the chain pass through the board, and connect it with the coating of a large jar; fix the exterior end to a discharging rod, and then discharge the jar; a beautiful spark will be seen at every link of the chain. The illuminations to be produced by a chain are capable of an infinite variety of modifications.

EXPERIMENT LXXXVI. *Luminous discharger.* Place spots of tin-foil, at equal distances from each other, on a piece of bent glass, and let the ends of the glass be furnished with brass balls, and a glass handle be fixed to the middle of the bent glass. The instrument will serve as a discharger, and at the same time exhibit, at each separation of the tin-foil, the electric light. The same end is answered by connecting an iron chain with the two balls.

EXPERIMENT LXXXVII. *Illumination by a revolving spark. Fig.* 98, *plate* 5, represents several spiral tubes placed round a board; a glass pillar is fixed to the board, and on this pillar is cemented a metal cap, carrying a small steel point; a brass wire, furnished with a ball at each end and nicely balanced, is placed on this point: place the middle of this wire under a ball proceeding from the conductor, so that it may receive a continued spark from the ball; then give the wire a rotative motion, and the balls in revolving will give a spark to each ball of the spiral tube, which will be communicated from thence to the board; forming, from the brilliancy of the light and its rapid motion, a very pleasing experiment.

All these experiments on the interrupted spark may be pleasingly and beautifully varied, and the spark made to appear of different colours, at the pleasure of the operator.

Fig. 92 represents a small glass tube, stopped at one end with a piece of cork; k, a wire passing through a piece of cork, fitted into the other end of a tube; the upper part of the wire is furnished with a brass ball, the end of the wire within the tube is bent at right angles to the rest of the wire.

EXPERIMENT LXXXVIII. *To perforate a glass bottle by the electric spark.* Take out the upper cork and wire; pour some salad oil into this tube, and then fit in the cork and push down the wire, so that the end of it may be near or rather below the surface of the oil; present the ball towards a prime conductor, holding the finger, or any other non-conductor, opposite the bent end of the wire; and, when a spark passes from the conductor to the brass ball, another will pass from the end of the wire and perforate the glass: the oil will be curiously agitated.

This experiment appears more beautiful when it is made in the dark. After the first hole is made, turn the end of the wire round towards another part of the glass tube, and a second hole may be made in the same manner.

Mr. *Lullen* produces very considerable effects by passing the shock through wires that were inserted in tubes filled with oil. The spark appears larger in its passage through oil than when it passes through water.

Mr. *Vilette* filled a dish of metal with oil, and, when he had electrified the dish, he plunged a needle into the oil, and received a very strong spark as soon as the point of it came within a small distance of the dish. A small cork ball being made to swim in this oil, upon the approach of the thick end of the stalk of a lime, it plunged to the bottom, and immediately rose up again.

The separation between the pieces of tin-foil, in Experiment 62, forms a resistance which hinders the immediate reception of the electric fluid, and thus, in some measure, prevents the common action of the point on the conductor; or, the power of a point, to prevent an explosion, depends on its having a perfect uninterrupted metallic communication with the earth; though this is not always sufficient, as may be seen by Experiment 63, where the fluid is concentrated and collected by the non-conducting substance which surrounds the point; a case similar, in many respects, to the conductors which are erected for the preservation of buildings.

PHOSPHORIC EXPERIMENTS.

Experiment lxxxix. *Phosphorus illuminated.* Take some of the powder of *Canton*'s phosphorus, and, by means of a little spirit of wine, stick it all over the inside of a clean glass phial, then stop the bottle, and keep it from the light. To illuminate this phosphorus, draw several strong sparks from the conductor, keeping the phial about two or three inches from the sparks so that it may be exposed to their light; the phial will afterwards appear luminous, and remain so for a considerable time.

Experiment xc. Cut out in pasteboard, or soft wood, the figure of a crescent or any of the planets; cover this equally with the white of an egg beat up till it is quite smooth, over which sift the phosphorus through a fine lawn sieve, then let it dry, and blow off all that is not fixed by the egg. To make the experiment, place the object in the communication between two directors, and discharge the jar, when the whole will become beautifully luminous; care must be however taken to hold the directors at a little distance above the phosphorus, for if it passes through it, the whole of the powder in the track of the fluid will be torn off.

Place a small key on the phosphorus, and discharge a Leyden phial over the phosphorus, and then throw the key off from it, and when it is exhibited in the dark, the form of the key and all its wards will be perfectly seen.

As the experiments on phosphorus are in themselves exceedingly curious, and appear to me to be intimately connected with the nature of electricity, I hope I shall not be thought to have deviated too far from the subject of this Essay, by introducing some experiments of Mr. *Wilson* on this subject; the more so, as the producing the prismatic colours is by no means difficult, as little more is required than a few oyster shells, and a good fire of any kind. For, if those shells are thrown carelessly into the middle of the fire, and continued there for a proper time, which may be for ten minutes, a quarter, half, or three quarters of an hour, according to the thickness and compactness of the shells and the degree of fire they are exposed to, they will exhibit lively prismatic colours, after they are removed from the sun into the dark suddenly, and the eyes have been previously prepared a little to receive them. Mr. *Wilson* excited also the light of these shells with electricity in the following manner:

EXPERIMENT XCI. He placed upon a metal stand, which was rounded at top, and about half an inch in diameter, a prepared shell that would exhibit the prismatic colours very lively on the upper surface of this shell, and near the middle, where the colour-making parts predominated, he brought the end of a metal rod, and then connected the two metals properly with the coatings of a charged phial, in order to discharge the fluid. In this circuit there was left designedly an interval of about three inches, unoccupied by metal and next one side of the glass; the discharge was made by completing the circuit with metal where the interval was left. The shell at that instant was lighted up to an exceeding great advantage, so that all the colours appeared perfectly distinct and in their respective places, answering to their different colour-making parts. These colours continued visible several minutes, and, when they ceased to appear, a white purplish light occupied their places, which lasted for a considerable time. And, notwithstanding this experiment was repeated with the same and other shells, the colours continued in their respective places, and nearly of the same degree of brilliancy; excepting, that in or near those parts where the explosion took place a few scales were driven off.

EXPERIMENT XCII. *On firing spirit of wine by the electric spark.* Let any person stand on the insulating stool, and connect himself by a wire or chain with the prime conductor, he will then exhibit the same appearances which are obtained from the conductor, and will attract light bodies, give the spark, &c. and thus afford a pleasing mode of diversifying every experiment. It is absolutely necessary, to the complete success of this experiment, that no part of the cloaths touch the floor, table, &c. and that the glass feet be carefully dried: a sheet of dry brown paper placed under the stool, will be found of considerable service, by rendering the insulation more complete.

If the insulated person lays his hand on the cloaths of one that is not so, especially if they are woolen, they will both feel as it were many pins pricking them, as long as the cylinder is in motion.

Experiment xciii. *To fire spirits of wine with the electric spark.* Heat the ladle, I, *pl.* 3, *fig.* 35, then pour a small quantity of spirits of wine into it, and fix it by its handle to the end of the prime conductor; or fire the spirits, and blow them out a few minutes before the experiment is made; take a spark through the middle of the ladle with a brass ball, and the spirits will be fired by it.

Or, let a person standing on an insulated stool, and connected with the prime conductor, hold the ladle with the spirits in his hand, and let a person on the floor take a spark through them, and they will be fired. The experiment answers equally well, if the person on the floor holds the ladle, and the insulated person takes the spark.

Experiment xciv. The foregoing experiment may be agreeably diversified in the following manner. Let one electrified person, standing on an insulated stool, hold the spirits; let another person, standing also on an insulated stool, hold in his hand an iron poker, one end of which is made red hot: he may then apply the hot end to the spirits, and even immerge it in them, without firing them; but, if he put one foot on the floor, he may set the spirits on fire with either end.

Experiment xcv. The spirits cannot be kindled by an insulated person; because, as the electric fluid cannot escape through him to the earth, he is incapable of drawing a spark sufficiently strong to inflame them, and hot iron will seldom or never set spirits on fire.

OF INFLAMMABLE AIR, AND THE PISTOL FOR FIRING INFLAMMABLE AIR BY THE ELECTRIC SPARK.

A species of air, which is inflammable, is frequently generated in coal mines: the air also emitted by stirring the mud of some standing waters, has been found to be inflammable. Putrescent animal matter also emits this fluid. It may be obtained by distillation from wax, pitch, amber, coals, and other phlogistic substances. The following is the most convenient method to procure it: put some small nails or iron filings into the glass bottle, r, *pl.* 3, *fig.* 38; cover these with water, then add to this a little oil of vitriol, about one quarter of the quantity there is of water; put the ground end of the bent tube into the mouth of the bottle, and pass the other end through the water of the bason, T, into the neck of the bottle K, which is filled with water, and inverted in the bason: the bottle, K, must be supported during the operation. In a little time the mixture will effervesce, and emit a fluid which will pass through the bent tube, go into the bottle, K, and at last fill it totally, expelling the water; the bottle is then to be removed, and corked as expeditiously as possible.

Fig. 39 represents a brass pistol for inflammable air; a b is the chamber of brass, to the mouth, a c, of which a cork is fitted; a perforated piece of brass, g, screws on to the bottom of this chamber, (this piece is represented by itself in *fig.* 40;) a glass tube, f, is cemented into the perforation of this piece, and a brass wire is also cemented into the glass tube; one end of this wire is furnished with a ball, the other extremity is bent, so as to come within about a tenth of an inch of the brass piece. *Fig.* 41 is a brass cap which screws on the pistol, to preserve the glass tube from any accident. The air with which the pistol is to be charged should be kept in a corked bottle: take out the cork and apply in the same instant the mouth of the pistol to the opening of the bottle, and the common and inflammable air will mix together, because the former being heavier than the latter will naturally descend; keep the pistol in this situation about fifteen seconds, then remove it, and cork both the bottle and pistol with the utmost expedition.

If the pistol is held too long over the bottle, and is entirely filled with inflammable air, it will not explode.

DESCRIPTION OF ANOTHER APPARATUS FOR MAKING INFLAMMABLE AIR, AND FILLING THE AIR PISTOL, &c.

This apparatus consists of the following articles:

1. A glass funnel.
2. A small glass tumbler.
3. A bladder tied to a stop-cock.
4. A brass pipe passing through a cork; which cork is made tapering, to fit the neck of a common wine bottle: the upper part of the pipe has a male screw, to fit the screw on the lower end of the stop-cock.
5. An air pistol, furnished with a valve at the end *b*, *fig*. 39; the wire passing through a glass tube, and to which the spark is to be given, is fitted into the side of the pistol. At the end, *b*, of the pistol is a male screw, which fits the lower end of the stop-cock.
6. A box with iron filings.
7. A small measure which will hold the proper quantity of iron filings.
8. A brass tube and hollow flyer; the lower end of the brass tube fits the stop-cock.

Soak the bladder in water which is lukewarm, in order to soften it; and then render it pliable, by blowing air into it and squeezing it out again. After this, screw the conical pipe with the cork into the lower end of the stop-cock, and it is ready for use. Then take a common quart wine bottle, and put into it a little hot water to warm it. Pour as much oil of vitriol into the tumbler as will about half fill it, and mix this in another tumbler with about three times the quantity of cold water. Throw the warm water out of the bottle, and put a measure of iron filings into it; then pour out the diluted vitriol through the glass funnel upon the iron filings. As soon as the effervescence begins, put the cork with its pipe into the neck of the bottle, and the inflammable air which is generated by the mixture will enter into and gradually swell the bladder. When this is full, shut the stop-cock, and remove the bladder from the bottle.

The bladder being thus filled, screw the bottom of the piston upon the stop-cock; compress the bladder, and introduce by this means about as much inflammable air as you judge will fill one third of its capacity, and put the cork immediately into the muzzle of the pistol. To form a circle of fire with inflammable air, fill the bladder as before, unscrew the conical tube from the stop-cock, and screw the brass fly in its place, open the cock, and compress the bladder; the air will pass through the fly, and set it in motion: light the air at the end of the pipe, and a beautiful circle of fire will be formed by the motion of the bent tube, and the fired air which issues from its points. The pistol is fired as in Experiment 69.

If too great a quantity of inflammable air is introduced into the pistol, it will not explode: to remedy this, blow strongly into the muzzle of the pistol; this will force out a quantity of the inflammable air, and occasion a quantity of common air to enter the pistol, which will then readily explode.

The bottle should be taken into the open air and be well washed, as soon as the bladder is filled.

EXPERIMENT XCVI. *To fire inflammable air.* Bring the ball of the pistol which is charged with inflammable air near the prime conductor, or the knob of a charged jar; the spark which passes between the end of the wire, f, and the piece, g, *fig.* 40, will fire the inflammable air, and drive the cork to a considerable distance. This air, like all other, requires the presence either of common air, or else of vital air, to enable it to burn; but, if it is mixed with a certain quantity of common air, an explosion will take place in passing the electric spark through it.

Mr. *Cavallo* recommends a pistol made in the following manner, to those who wish to make experiments on the explosion of inflammable and dephlogisticated air, or with known quantities of common and inflammable airs. It consists of a brass tube, about one inch in diameter and six inches long, to one extremity of which a perforated piece of wood is securely fitted; a brass wire, about four inches long, is covered, except its ends, first with sealing-wax, then with silk, and afterwards with sealing-wax again. This wire is to be cemented in the perforation of the wooden piece, so as to project about two inches within the tube, the rest is on the outside; that part of the wire which is within is bent, so as to be only about the tenth of an inch from the inside of the brass tube.*

To use this pistol, fill it with, and then invert it into a bason of water; make the required quantity of inflammable and common air in another vessel, by putting in known and proportionable measures of each; introduce this mixture into the pistol, and then stop it with a cork; take the pistol out of the water, and pass in the usual manner the spark of a charged jar through it, and the inflammable air will be fired.

The instruments for firing the inflammable air with the electric spark, are often made in the shape of a cannon, *plate* 4, *fig*. 73.

* *Cavallo* on Air, p. 818.

CHAP. IX.

OF ELECTRIFIED POINTS.

EXPERIMENT XCVII. *Dissipation of electricity by a point.*

PRESENT the pointed end of a wire towards a conductor which is positively electrified, a lucid globular point or star will appear on the point, and the electric fluid will be evidently conveyed away and dissipated from the conductor.

EXPERIMENT XCVIII. *Brush of electric light.* Present a pointed wire towards a conductor that is electrified negatively; a lucid cone or brush will be seen diverging from the point, and the quantity of fire will be increased.

EXPERIMENT XCIX. *Star of electric light.* The lucid star is seen on the collecting points of a positive conductor, while a diverging cone will appear on a point placed at the end of the conductor.

To determine the direction of the electric fluid, has ever been an object of considerable importance to the electrician; as it would enable him to decide on the truth of those theories, which have been invented to account for its phenomena, and greatly assist him in the progress of future discovery: to this end, much stress has been laid on the different appearance of the light which is perceived on the pointed ends of electrified conducting substances; as these have been supposed to elucidate fully this interesting question.

The electric fluid appears as a diverging stream darting forwards into the air, from a point electrified positively. The luminous appearance on a point negatively electrified, is that of a small little globule or star.

Now, as the air is known to resist the motion of the electric fluid, the rays of it would by this resistance be made to diverge; therefore, when this fluid is darting from a point into the air, it will assume the form of a lucid cone or brush.

To this it has been objected, that these rays may possibly be converging from so many points in the air towards the point, and not diverging from it; but, as there does not appear any reason why a visible ray should break out from one place in the atmosphere more than another, the former account seems more conformable to nature, and the known laws of other fluids. The air resists the motion of the electric fluid equally. Therefore, when this fluid is coming from the air towards a pointed conductor, it would percolate slowly and invisibly through the air, but equally on all sides, till it comes so near as to be able to break through the intermediate space; but, as this will be equal or nearly so all around, the negative electricity must appear like a steady luminous globule on the point.* Notwithstanding the apparent probability of the above reasoning, it may still be objected, that no decisive conclusion can be drawn from these appearances, as they may be varied by augmenting or diminishing the volume of the pointed body, and by a variety of other circumstances.

Experiment c. A lucid cone appears on the collector of a negative conductor, and a lucid star on a point placed on the opposite end of the conductor.

Experiment ci. Bring an excited glass tube near a point that is fixed at the end of a positively electrified conductor, and the luminous brush will be turned out of its direction by the action of the excited tube; if the tube is held directly opposite to the point, the brush will vanish.

Experiment cii. Fix the point to the end of the negative conductor, the lucid star will turn towards the excited tube.

Experiment ciii. *Action of flame.* Put a wire, which has a ball at one end, into the hole at the end of a positive conductor, place a lighted

* Encyclopædia Britannica, p. 2699.

candle so that the middle of the flame may be even with the middle of the ball, and about an inch from it; turn the machine, and place the same wire at the end of the negative conductor, the appearance will be reversed, and the knob will soon be heated by the flame of the candle which is carried towards it.

EXPERIMENT CIV. *Electric fly.* Fix a pointed wire in the hole on the upper side of the conductor, then place the center of the brass cross, K, *plate* 3, *fig*. 34, upon the point, the ends of which cross are all bent one way; electrify the conductor, and the cross will turn upon its center with great rapidity. If the room be darkened, a circle of light will be formed by the electric fluid on the points of the wires. The re-action of the air on the diverging cone of electric matter gives the retrograde motion to the points of the wire.

The fly turns round in the same direction, whether it is electrified negatively or positively; though it will not move in vacuo, unless the finger, or some other conductor, is applied to the glass receiver opposite to one of the points, it will then begin to move, and continue to do so briskly till the glass is charged.

EXPERIMENT CV. Electrify the two insulated wires, M N, O P, *fig*. 35, and the resistance of the air against the electric stream from the point of the fly, L, the axis of which rolls on the wires, will force the fly up the declivity of the inclined plane, M N, o P.

Experiment cvi. *Fig.* 36 represents a small crane, which will move from the same cause as the foregoing, and raise a small weight.

Experiment cvii. Several flyers may be made to turn at the same time, see *fig.* 37, and many other pleasing experiments may be contrived on the same principle; or the flyers may be placed one above another, diminishing gradually in size, and forming, when electrified, a luminous cone; the circles of light will be more brilliant, if the ends of the wires are covered with a thin coating of grease, sealing-wax, or sulphur.

Experiment cviii. *Spark from a point immersed in oil.* Immerge a metallic point in a metal vessel nearly filled with oil of vitriol, and placed on an electrified conductor, scarce any spark will pass to the point, although it is held very near the bottom of the vessel. If this is filled with essential oil of turpentine, a small light may be seen from time to time in the body of the fluid. If common oil is used, the point will take strong sparks, and the electric fluid, in endeavouring to reach it, will occasion an ebullition in the oil.

So that the electric spark depends in a great measure on the conducting power of the medium through which it passes.

ELECTRIC BOATS.

If small boats or little swans, &c. are made of cork or light wood, they may be attracted and made to swim in any direction, by applying a finger towards them: a fine needle stuck into the end of the boats, in the manner of a bowsprit, will cause them to be repelled from the hand held over it, and they may be steered by it, stern foremost, to what point of the compass you please. The boats might have the addition of sails to them, and might then be made to move briskly before an electrical gale, from the point of a wire held in the hand.

The operator in these tricks would certainly be looked upon as a magician, if the electrical machine be kept out of sight. But a more striking appearance would be a number of these boats, with each of them a twirling fly about an inch in length fixed to the top of the mast; the hand held over them would set them all in motion: in the dark, they would appear as so many rings of fire, moving in various courses, and following the hand in any direction.

When a few young persons have nothing else to do, they might very innocently amuse themselves, by making a representation of a kind of sea-engagement between these boats. Supposing each of them large enough to hold a small coated phial without sinking, these phials may be charged, some of them positively on the inside, others negatively; they may then be placed at the bow of the boat, with the wire, ball, and uncoated part of the phial projecting over; a small brass chain should be made to touch the outward coating of the phial, and the other end brought over the stern of the boat, and hung so as to touch the water. The boats being then put into a trough of water, and pretty highly charged, they will soon be in motion; those that are electrified alike will repel each other, and those possessed of a contrary electricity will be attracted, till the balls of the two phials approach pretty near together; they will then discharge their contents with a loud explosion, and the boats will afterwards sheer from each other.*

When the electric fluid percolates a wooden point, the stream or cone which issues from it seems diluted and something similar to the purple electric light which is obtained in vacuo. The action of the electric fluid on the air, by an electrified point, produces a sensible aura or wind of sufficient force, as is seen above, to put light bodies in motion, or disturb the flame of a candle, and occasion an undulation in the fluids. The

* *Becket's* Essay on Electricity, p. 36.

action of the fluid is so modified by points, as to produce an agreeable sensation, resembling a gentle breathing; this sensation may be rendered more or less stimulating, by the resistance the fluid meets with in its action on our bodies, an effect which is productive of great advantages in medical electricity.

MR. NICHOLSON, UPON THE LUMINOUS APPEARANCES OF ELECTRICITY, AND THE ACTION OF POINTS.

He observes, that the escape of negative electricity from the ball is attended with the appearance of straight sharp sparks, with a hoarse or chirping noise. When the ball was less than two inches in diameter, it was usually covered with short flames of this kind, which were very numerous.

When two equal balls were presented to each other, and one of them was rendered strongly positive, while the other remained in connexion with the earth, the positive brush or ramified spark was seen to pass from the electrified ball; when the other ball was electrified negatively, and the ball, which before had been positive, was connected with the ground, the electricity (passing the same way, according to *Franklin)* exhibited the negative flame, or dense, straight, and more luminous spark, from the negative ball; and when the one ball was electrified *plus*, and the other *minus*, the signs of both electricities appeared. If the interval was not too great, the long zig-zag spark of the *plus* ball struck to the straight flame of the *minus* ball, usually at the distance of about one-third of the length of the latter from its point, rendering the other two-thirds very bright. Sometimes, however, the positive spark struck the ball at a distance from the negative flame. These effects are represented in *plate* 1, *fig*. 1, 2, 3.

Two conductors of three-quarters of an inch diameter, with spherical ends of the same diameter, were laid parallel to each other at the distance of about two inches, in such a manner as that the ends pointed in opposite directions, and were six or eight inches asunder. These, which may be distinguished by the letters P and M, were successively electrified as the balls were in the last paragraph. When one conductor, P, was positive, *fig*. 5, it exhibited the spark of that electricity at its extremity, and struck the side of the other conductor, M. When the last-mentioned conductor, M, was electrified negatively, *fig*. 4, the former being in its turn connected with the earth, the sparks ceased to strike as before, and the extremity of the electrified conductor, M, exhibited negative signs, and struck the side of the other conductor. And, when one conductor was electrified *plus*, and the other *minus*, *fig.* 6, both signs appeared at the same time, and continual streams of electricity passed between the extremities of each conductor to the side of the other conductor opposed to it. In each of these three cases, the current of electricity, on the hypothesis of a single fluid, passed the same way.

In drawing the long spark from a ball of four inches diameter, it was found of some consequence that the stem should not be too short, because the vicinity of the large prime conductor altered the disposition of the electricity to escape; a set of experiments were therefore made, the result of which shewed, that the disposition of balls to receive or emit electricity is greatest when they stand remote from other surfaces in the same state; and that between this greatest disposition in any ball, whatever may be its diameter, every possible less degree may be obtained by withdrawing the ball towards the broader or less convex surface, out of which its stem projects, until at length the ball, being wholly depressed beneath that surface, loses the disposition entirely. From these experiments it follows, that a variety of balls is unnecessary in electricity; because any small ball, if near the prime conductor, will be equivalent to a larger ball whose stem is longer.

From comparing some experiments, made by himself many years ago, with the present set, he considered a point as a ball of an indefinitely small diameter, and constructed an instrument consisting of a brass ball of six inches diameter, through the axis of which a stem, carrying a fine point, was screwed. When this stem is fixed in the prime conductor, if the ball be moved on its axis in either direction, it causes the fine point either to protrude through a small hole in its external surface, or to withdraw itself; because by this means the ball runs along the stem. The disposition of the point to transmit electricity may thus be made equal to that of any ball whatsoever, from the minutest size to the diameter of six inches. See *fig.* 7, A.

The action of pointed bodies has been a subject of discussion ever since it was first discovered, and is not yet well explained. To those who ascribe this effect to the figure of electric atmospheres, and their disposition to fly off, it may be answered, that they ought first to prove their existence, and then shew why the cause which accumulated them does not prevent their escape; not to mention the difficulty of explaining the nature of negative atmospheres. If these be supposed to consist of electrified air, it will not be easy to shew why a current of air passing near a prime conductor does not destroy its effects.

The opinion supported by the celebrated *Volta* and others, that the point is the coating to an infinitely small plate of air, does not appear better founded; for, such a plate must be broken through at a greater distance, only because higher charged; whence it would follow, that points should not act but at high intensities. As a proof that the charge has little to do here, if a ball be presented to the prime conductor at the same time that a point proceeds from the opposite side of the ball, the electricity will pass by the point, though it is obliged to go round the ball for that purpose; but it can hardly be doubted, that whatever charge obtains in this case is on the surface of the ball next the conductor, and not on the remote side to which the electricity directs its course.

Achard's experiments with a number of pointed cones, screwed in a plate of metal, and likewise the pointed apparatus before described, shew that the effect of points depends on the remoteness of their extremities from the other parts of the conductor. This leads to the following general law:

In any electrified conductor, the transition or escape of electricity will be made chiefly from that part of the surface which is the most remote from the natural state.

Thus, in the apparatus of the ball and stem, the point, having a communication with the rest of the whole conductor, constantly possesses the same intensity; but the influence of the surrounding surface of the ball diminishes its capacity. This diminution is less the farther the ball is withdrawn, and consequently the point will really possess more electricity, and be more disposed to give it out when it is prominent than when depressed. The same explanation serves for negative electricity.

The effect of a positive surface appears to extend further than that of a negative; for, the point acts like a ball when considerably more prominent if it be positive, than it will if negative. This property was used some years ago for the construction of an instrument to distinguish the two electricities.*

For the sake of conciseness many facts are passed over, which have presented themselves in the course of the experiments on the two electricities; there is, however, scarcely any experiment made with the positive power, which will not afford a result worthy of notice, if repeated with the negative.

When we consider, that our machines can cause a ball of an inch and half diameter to act like a point, and that our apparatus makes a point act like a ball; if, at the same time, we remark the small elevation of our conductors for lightning

* Introduction to Natural Philosophy, vol. ii. p. 320.

above the extended surface of the ground, and the small size of the balls proposed by some to be used as terminations; the dispute, which was so much agitated respecting them, will perhaps be found to relate to a very minute circumstance, among the many which govern the great operations of nature. It does not seem probable that any conductor would act silently if the main course of the electricity of a negative cloud were to pass through it, and many would probably receive the stroke from a positive cloud. It does not, however, follow from this, that they might not conduct it with safety.*

* Mr. *Nicholson*, in his valuable Journal of Natural Philosophy, vol. ii. p. 438, has the following remarks, which I think proper to be inserted here.

"The phenomena of the two electricities called *plus* and *minus*, are singularly distinct in almost every experiment which can be made with the exhibition of electric light. Paper is a good substance for observing the visible passage of electricity. If a strong plus electric stream be let fall on the flat side of an uninsulated sheet of paper, it forms a beautiful star about four inches in diameter, consisting of very distinct radii not ramified. The minus electricity, in circumstances perfectly similar, throws many pointed brushes to the paper, but forms no star upon it. In this experiment, I used a machine with a cylinder of seven inches diameter.

"Hence it seems to follow, that a hollow ball of paper, or a glass globe covered with paper, might form an amusing part of the electrical apparatus for experiments in the dark." Edit.

CHAP. X.

OF THE LEYDEN PHIAL, OR JAR.

THE experiments upon the Leyden jar are some of the most interesting in electricity; they excited the attention of the philosopher to this subject more than any other experiment, and are still viewed with wonder and surprize.

EXPERIMENT CIX. *Charging and discharging in general the Leyden jar.* Place the brass ball of a coated jar in contact with the prime conductor, while the outside communicates with the table; turn the cylinder, and the jar will in a little time be charged, or modify the electric fluid in a peculiar manner. To discharge the jar, or restore it to its natural state, bring one end, or one of the balls of the discharging rods, *plate* 1, *fig.* 1 and 2, in contact with the outside coating, and let the other be brought near the knob of the jar which communicates with the inside coating; a strong explosion will take place, the electric light will be visible, the report very loud, and no effect made on the operator.

EXPERIMENT CX. *The electric shock.* Charge the Leyden jar, then touch the outside coating with one hand, and the knob with the other, the jar will be discharged, and a sudden peculiar sensation will be perceived, that is called the *electric shock.*

The shock, when it is taken in this manner, generally affects the wrists, elbows, and breast: when the shock is strong, it resembles an universal blow. This peculiar sensation is probably owing to the two-fold and instantaneous action of the electric fluid, which enters and goes out of the body, and the various parts through which it passes, at one and the same instant. It has been also observed, that nature has appointed a certain modification of the electric fluid in all terrestrial bodies, which we violate in our experiments; when this violation is small, the powers of nature operate in a gentle manner to rectify the disorder we have introduced; but, when the deviation is considerable, the natural powers restore the original constitution with extreme violence.

If several persons join hands, and the first touches the outside of a charged jar, and the last the knob, the jar will be discharged, and they will all feel the shock at the same instant: but, the greater the number of persons that join hands to take a shock, the weaker it is.

The force of the shock is in proportion to the quantity of coated surfaces, the thinness of the glass, and the power of the machine; or, the effect of the Leyden jar is increased, in proportion as we destroy the equilibrium on the surfaces.

A given quantity of electricity, impelled through our body with a given force, produces a weaker sensation than twice that quantity impelled with half that force; and, consequently, the strength of the shock depends rather more on the quantity of fluid which passes through our body, than on the force with which it is impelled. Yet, the force of an explosion seems to depend more on the degree to which the fluid is compressed than on the quantity; hence a small phial fully charged will act nearly as strong as a large jar which is half charged.

If a charged jar is coated very high, it will discharge itself before it has received near the charge it would take if the coating was lower. If it is coated very low, this part of the surface may be charged very high, but a considerable part of the glass is not charged at all.

When a jar is charged very high, it will often explode or discharge itself over the glass from one coated surface to the other; or, if the glass is thin, it will make a hole through it, and swell the coating on both sides, the glass in the hole will be pulverized, and very often a variety of fissures will proceed from it in various directions.

A Leyden jar very often recovers its electricity, in a small degree, after a discharge has been made: this second explosion is called the residuum of a charge.

The form or size of the glass is no ways material to the receiving of a charge.

To avoid receiving the electric shock, be careful never to touch the top and bottom of the jar at the same time, and never to enter a circuit formed between the inside and outside of a jar; for, the effect of a Leyden jar depends entirely on the reciprocal action of the two surfaces, and does not take place when either is touched separately. By attending to this observation, jars of any size may be handled with safety. Indeed, the human frame makes so little resistance to the free passage of this subtile agent, that no other inconvenience will attend a shock from a common-sized charged jar, than a transient disagreeable sensation.

Touch the knob of a charged jar, no shock will ensue; but the finger, or part that touches the ball of the jar, will be affected with a sharp sensation, as if it had been pricked with a needle. The discharge is silent and without any explosion, when the communication between the two sides of the jar is made by imperfect conductors.

A charged phial set upon electric substances, may be taken hold of without danger, either by the coating or the wire; a small spark only will proceed from either.

Magic picture. The magic picture is a coated pane of glass, proper to answer the purpose of the Leyden experiment; over the coating on one side is pasted a picture, on the other side a piece of white paper is pasted, so as to cover the whole glass; it is then put into a frame, with the picture uppermost, and a communication is formed from the tin-foil of the under side to the bottom rail of the frame of the picture, which rail is covered with tin-foil.

Lay the picture on the table, with the print uppermost, and a piece of money on it; let a chain fall from the conductor to the print, turn the cylinder, and the plate of glass will soon be charged; now take hold of the picture by the top rail, and let another person take hold of the bottom rail, and endeavour to take off the piece of money; in doing this he will receive a shock, and generally fail in the attempt.

DR. FRANKLIN'S THEORY OF THE LEYDEN JAR.

Glass is supposed to contain at all times, on its two surfaces, a large quantity of the electric fluid, which is so disposed, that, if you increase the quantity on one side, the other must throw off an equal proportion; or, when one side is positive, the other must be negative. Now, as no more of the electric fluid can be forced on one side, than can go off on the other, there is no more in the jar, after it is charged, than was there before; the quantity is neither increased or lessened on the whole, though a change may be made in its place and situation; *i. e.* we may throw an additional quantity on one of its sides, if at the same time an equal quantity can escape from the other, and not otherwise. This change is effected by lining parts of its two surfaces with a non-electric; through the mediation of which, we are enabled to convey the electric fire to every physical point of the surface we propose to charge, where it exerts its activity in repelling the electric particles naturally belonging to the other side; all of which have an opportunity of escaping by the lining in contact with this surface, which for that purpose must communicate with the earth: when the whole quantity belonging to this surface has been discharged, in consequence of an equal quantity thrown upon the other surface, the jar is charged as much as it can possibly be. The two surfaces are at this time in a state of violence; the inner, or positive side, strongly disposed to part with its additional fire, and the outer, or negative side, equally desirous to attract what it has lost; but neither of them capable of having a change in its state effected, without the equal and cotemporary participation of the other. Notwithstanding the vicinity of these two surfaces, and the strong disposition of the electric fluid contained in one of them to communicate its superabundance to the other, and of that to receive it, yet there is an impenetrable barrier between them; for, so impermeable is glass to the electric fluid, though it permits one side of it to act upon the other, that its two surfaces remain in this state of contrariety, till a communication is formed between them *ab extra*, by a proper conductor, when the equilibrium is suddenly and violently restored, and the electric fluid recovers its original state of equality on the two sides of the glass.

THE LEYDEN JAR CONSIDERED IN A DIFFERENT POINT OF VIEW.

We have already shewn, that whenever a quantity of the electric fluid is brought within a certain distance of the surface of any body, whether metal, wood, or glass, it will always produce on that body a contrary electricity; and this more readily and permanently, when the body has a communication with the earth.

The equilibrium will not be restored so long as the power continues of the same force, and acting at the same distance; but, the nearer this power is brought to the surface, the greater is the effect it will produce. It has also been shewn, that the electric fluid will communicate these powers through glass, nearly as well as through air.

Now, as glass resists the passage of the fluid more than wood or metal, the fluid will be longer in passing through a given length of glass, than through the same length of wood or metal.

But, by means of the metallic coating on one side of the glass, the electric fluid is placed in the most advantageous situation for producing a strong and uniform action on the contrary side, on which the resistance is lessened with as great advantages by the other metallic coating, which is connected with the earth; and this contrariety will continue till the equilibrium is restored by connecting the opposite side with a conductor.

When an electric is excited, the two powers are said to be separated: they are also known to repel their own particles, and attract the contrary. When one side of a jar is made positive, may it not repel the positive electricity from the other side, separating it from the negative, which is strongly attracted through the glass?

The outside of the jar cannot then be said to be deprived of its electricity, but only has its fluid changed; and when the fluids are separated, they are ever eager to conjoin again.*

* See *Eeles*'s Philosophical Essays; *Wilson*'s Short View of Electricity; and *Milner*'s Observations on Electricity.

COMBINED APPARATUS.

The apparatus represented at *plate* 3, *fig*. 49, will be found exceedingly convenient for making a variety of experiments on the Leyden jar. I have endeavoured to combine the parts of it in such a manner, as to render the apparatus extensively useful, without being complicated. A is an insulated pillar of glass, which is screwed to the wooden foot, B: all the different parts of the apparatus may be screwed alternately on this pillar. C D is an exhausted tube of glass, capped at each end with brass: at the end, D, is a valve, properly secured under the brass plate; a brass wire, with a ball, projects from the upper cap; a pointed wire proceeds from the bottom plate; this tube is called the luminous conductor. The flask represented at E, is called the Leyden vacuum. It is furnished with a valve under the ball, E; this ball unscrews, in order to come more readily at the valve: a wire with a blunt end projects a little below the neck of the flask; the bottom of the flask is coated with tin-foil; a female screw is cemented to the bottom, in order to screw it on the pillar A.

F is a syringe to exhaust the air occasionally, either from the luminous conductor, or the Leyden vacuum. To do this, unscrew the ball, E, of the

Leyden vacuum, or the plate, c d, of the luminous conductor, and then screw the syringe in the place of either of these pieces, being careful that the bottom of the female screw, G, bears close against the leather which covers the shoulders, then work the syringe, and in a few minutes the glasses will be sufficiently exhausted. H and I are two Leyden jars, each of which has a female screw fitted to the bottom, in order that they may be conveniently screwed on the pillar, A. The jar, H, is furnished with a brass belt, that it may screw sideways on the pillar, A. K and L are two small wires, which are to screw occasionally into either the ball E, the knobs of the jars, e or f, the cap C, or the socket g, on the top of the pillar: the balls may be unscrewed from these wires, which will then exhibit a blunt point. M is a wooden table to be screwed on the glass pillar occasionally.

EXPERIMENTS ON CHARGING AND DISCHARGING THE LEYDEN PHIAL, INTENDED TO ELUCIDATE AND CONFIRM DR. FRANKLIN'S THEORY.

Experiment cxi. *To shew, that except the fluid goes off on one side, it can receive none on the other.* Screw a Leyden phial, whose coating is free from points, upon an insulated stand, and place it so that its knob may be in contact with the conductor, taking care that no conducting substance is near the coating of the jar; turn the cylinder round a sufficient number of times to charge the phial, then examine it with a discharging rod, and you will find it had received no charge; which shews clearly, that except the electric fluid can escape from one side of the jar, it can receive none on the other. If there are any points on the coating, or damp on the stand, the fluid will be carried off by them, and the jar will receive a small charge. The air which surrounds the coating will also sometimes carry off a small quantity of electricity.

Experiment cxii. Place the same insulated phial so that its knob may be about half an inch from the conductor, and while the cylinder is turning, hold a brass knob near the coating of the jar; this knob will receive a spark from the coating for every one that passes between the conductor and the knob, and the jar will in a little time be charged, by adding electricity to one side and taking it away from the other.

Experiment cxiii. Screw the phial, a, *plate* 3, *fig.* 42, on the insulated pillar d, and bring its knob in contact with the conductor; hold another jar, c, of the same size with a, so that its knob may be in contact with the outside coating of the jar, a; turn the cylinder, and when the jar, a, is charged, place c on the table, then unscrew a from its stand, and place it also on the table, but at some distance from the other; fit a brass ball to the bottom stem of the quadrant electrometer, and hold the electrometer by a silken string, so that the brass ball may touch the knob of the jar; observe at what height the index of the electrometer stands, and then remove it to the other jar, which will raise the index to the same height; shewing clearly, that the jar has thrown off from the outside as much electricity as it received on the inside.

EXPERIMENT CXIV. *Jar charged by the action of the two powers.* Place the knob of an insulated jar in contact with a positive conductor, and connect the outer coating with the cushion or a negative conductor; turn the cylinder, and the jar will be charged with its own electricity, the fluid from the exterior coating being transferred to the interior one. The jar is charged in this instance without any communication with the earth.

EXPERIMENT CXV. Charge the two jars, *fig.* 43, positively; connect their outside coatings by a wire or chain, then bring their knobs together; there will be no spark between them, and the jars will not be discharged, because neither side has any thing to communicate to the other.

EXPERIMENT CXVI. *Explosion through flame.* Charge the insulated jar, *fig.* 43, negatively, and the other positively; connect the coating by a chain, and bring the knobs towards each other, an explosion will take place, and the jars will be discharged. If a lighted candle is placed between the knobs, the explosion will be made through the flame in a beautiful manner, and at some inches distance. See *fig.* 44.

EXPERIMENT CXVII. *Discharge by the contrary power.* Fix a quadrant electrometer to the ball of a Leyden jar, and charge it negatively; when it has received a full charge, the index will stand at 90 degrees; then place the jar with its electrometer at the positive conductor; turn the cylinder, the electrometer will descend, and the jar will be discharged by the contrary electricity.

EXPERIMENT CXVIII. Insulate two Leyden jars; let their coatings be in contact, and while you charge the inside of one positively, let a person standing on the floor touch the top of the other with his finger, and it will be charged negatively.

EXPERIMENT CXIX. L M, *fig.* 45, represents a Leyden jar, which is furnished with moveable coatings of tin; the inner one, N, may be removed by the silken strings f, g, h; the jar may be taken from its outer coating.

Charge the jar, and then remove the coatings, bring a pair of pith balls towards the jar, and they will be strongly attracted by it; replace the coatings, and the jar will give a considerable shock; which shews, that the power or force of the charge is resident in the glass, and not in the coatings.

Experiment cxx. *Spotted jar.* T V, *fig.*46, represents a jar, whose exterior coating is formed of small pieces of tin-foil, placed at a small distance from each other. Charge this jar in the usual manner, and strong sparks of electricity will pass from one spot of tin-foil to the other in a variety of directions; the separation of the tin-foil making the passage of the fluid from the outside to the table, in a darkened room, beautifully visible. Discharge this jar, by bringing a pointed wire gradually near the knob T, and the interval between the spots will be pleasingly illuminated, and the noise will resemble that of small fired crackers. If the jar is discharged suddenly, the whole outside surface appears illuminated. The glass must be very dry.

Experiment cxxi. String a parcel of shot on a silken string, leaving a small space between each of them; suspend this from the conductor, so that it may reach the bottom of a coated jar, which is placed on an insulated stand; connect another string of shot to the bottom of the jar, and let it communicate with the table; turn the machine, and a vivid spark will be seen between each of the shot, both within and without the jar, as if the fire passed through the glass.

EXPERIMENT CXXII. Hold a jar which has no coating on the outside in the hand, and present its knob towards an electrified conductor; the fire, while it is charging, will pass from the outside to the hand, in a pleasing manner; on the discharge, beautiful ramifications will proceed from that knob of the discharger which is on the outside, all over the jar.

EXPERIMENT CXXIII. Let a chain be suspended from the conductor and pass into an uncoated jar, so that it does not touch the bottom; put the machine in action, and the chain will move round in order, as it were, to lay the fire on the inside of the jar, and thus charge it by degrees.

EXPERIMENT CXXIV. *Double jar. Fig.* 47 represents two Leyden jars, placed one over the other. Various experiments may be made with this double jar, which are very pleasing, and elucidate clearly the received theory.

Bring the outside coating of the jar, A, in contact with the prime conductor, and turn the machine till the jar is charged; then place one ball of the discharging rod upon the coating of B, and with the other touch the knob of the jar A, which will cause an explosion. Now place one ball of the discharger on the knob of A, and bring the other ball to its coating, and you have a second discharge. Again, apply one ball of the discharger on the coating of B, and carry the other to the coating of A, and it will produce a third explosion. A fourth is obtained by applying the discharger from the coating of A to its knob.

The outer coating of the upper jar communicating with the inside of the under one, conveys the fluid from the conductor to the large jar, which is therefore charged positively; the upper jar does not charge, because the inside cannot part with any of its electric fluid; but, when a communication is formed from the outside of A to the inside of B, part of the fire on the inside of A will be conveyed to the negative coating of B, and the jar will be discharged. The second explosion is occasioned by the discharge of the jar A; but, as the outside of this communicates, by conducting substances, with the positive inside of the jar B, if the ball of the discharging rod remains a small time after the discharge on the knob of A, part of the fire of the inside of A will escape, and be replaced by an equal quantity on the outside from the jar B, by which means A is charged a second time; the discharge of this produces the third, and of B, the fourth explosion.

The following pleasing variations of the foregoing experiment were communicated to me by Mr. *J. Fell*, of Ulverston.

A the upper jar, B the under jar.

Knob of A applied to the conductor, and the charge given.

1st discharge.	Balls of discharger from coating of A to knob of A.
2d ditto.	From coating of B to knob of A.
3d ditto.	From coating of B to coating of A.
4th ditto.	From coating of A to knob of A.

Coating of A applied to the conductor, and the charge given.

1st discharge.	Balls of discharger from coating of knob B to knob A.
2d ditto.	From coating of A to knob of A.
3d ditto.	From coating of B to knob of A.
4th ditto.	From coating of B to coating of A.
5th ditto.	From coating of A to knob of A.

Coating of A applied to the conductor, and the charge given; touch the knob of A with one ball of the discharger, the other ball communicating with the earth; then proceed as follows:

1st discharge.	Balls of discharger from coating of A to knob of A.
2d ditto.	From coating of B to knob of A.
3d ditto.	From coating of A to knob of A.
4th ditto.	From coating of B to knob of A.

Go on thus alternately, and fifteen, sixteen, or more discharges may be produced.

THE CONTRARY STATE OF THE TWO OPPOSITE SIDES OF A CHARGED LEYDEN JAR, SHEWN BY THEIR RESPECTIVE ATTRACTIVE AND REPULSIVE POWERS.

EXPERIMENT CXXV. Screw the jar, H, *fig.* 49, with the belt sideways, on the insulating stand, as in *fig.* 48, and charge it positively, then touch the knob with a pair of pith balls, these will diverge with positive electricity; hold another pair to the coating, and they will separate with negative electricity.

EXPERIMENT CXXVI. Electrify two pair of the pith balls which are fixed to the brass tubes, as in *plate* 2, *fig.* 22, by the knob of a positively charged jar, and place them at a small distance from each other; then push them together till the ends of the tubes are in contact, and the balls will remain in the same state they were in before they were brought together, because their electricity is of the same kind. The result is the same if both pair are electrified by the coating; but, if one pair is electrified by the coating, and the other by the knob, when they are brought in contact, they immediately close.

EXPERIMENT CXXVII. A cork ball, or an artificial spider made of burnt cork with legs of linen thread, suspended by silk, will play between the knobs of two jars, one of which is charged positively, the other negatively, and will in a little time discharge them.

EXPERIMENT CXXVIII. A ball suspended on silk, and placed between two brass balls, one proceeding from the outside, the other from the inside of a Leyden jar, when the jar is charged, will fly from one knob to the other; and, by thus conveying the fire from the inside to the outside of the jar, will soon discharge it.

EXPERIMENT CXXIX. An insulated cork ball, after having received a spark, will not play between, but be equally repelled by two jars which are charged with the same power.

EXPERIMENT CXXX. At *plate* 3, *fig*. 58, a wire is fixed to the under part of the insulated coated jar; b c, another wire fitted to, and at right angles with the former, a brass fly is placed on the point of this wire; charge the jar, and all the time the jar is charging, the fly will turn round; when the jar is charged, the needle stops. Touch the top of the jar with a finger, or any other conducting substance, and the fly will turn again till the jar is discharged. The fly will electrify a pair of balls positively while the jar is charging, and negatively, when discharging.

EXPERIMENT CXXXI. Place a clean, dry, and excited pane of glass, about one foot square, on an insulated box with pith balls; it will cause the balls to diverge with positive electricity, and they will continue to repel each other upwards of four hours in dry air. When the balls come together, remove the glass, and they will open with negative electricity; replace the glass, and they will close; remove it, and they will open again; and thus alternately, as long as any electricity remains in the glass.

If the pane of glass be placed in a frame of wood, and a light pith or cork ball be laid on its surface, on presenting towards it the end of a finger, or the point of a pin, the ball will recede from them with a very brisk motion, and may thus be driven about on the surface of the glass, like a feather in the air, by an excited tube. The ball being deprived of its electricity by the pin, it instantly flies to that part of the glass which attracts it most forcibly.

To excite the pane of glass, lay it upon a quire of large paper, well dried, and then rub it with a piece of clean dry flannel.

THE CONTRARY STATES OF THE DIFFERENT SIDES OF A LEYDEN JAR, AND THE DIRECTION OF THE ELECTRIC FLUID IN THE CHARGE AND DISCHARGE THEREOF, INVESTIGATED BY THE APPEARANCE OF THE ELECTRIC LIGHT.

We have already observed, that the different appearances of light on electrified points, were deemed a criterion of the direction of the electric fluid; that the luminous star shews a point in receiving the electric matter, whilst the luminous brush or cone indicates that it is proceeding from a point.

We shall now examine the state of the different sides of the Leyden jar by these appearances.

EXPERIMENT CXXXII. Screw the jar, I, on the insulating pillar, and the pointed wire into the hole g, place another pointed wire at the end of the conductor; bring the knob of the jar near this wire, and then turn the cylinder, a pencil of rays will diverge from the pointed wire in the conductor to the knob of the jar, at the same time another pencil of rays will diverge from the point at the bottom into the air. See *fig.* 50.

Repeat this experiment with the negative conductor, and a luminous star will appear on the end of each wire.

EXPERIMENT CXXXIII. Screw a pointed wire into the knob of the jar, see *fig.* 51, charge the jar positively, the fire will be received from the conductor by the pointed wire, and appear there as a luminous star, while the wire on the outside of the jar will throw off a diverging cone.

Fig. 52 represents the foregoing appearances reversed, by charging the jar negatively at the positive conductor.

This experiment may be further varied, by applying the jar to a negative conductor.

Experiment cxxxiv. After the jar is charged, as in the foregoing experiments, turn that wire from the cylinder which before was nearest to it, then put the machine in action, and the afflux and efflux will be more apparent than before; one point throwing off, and the other receiving the fluid with extreme avidity, which will in a little time discharge the jar.

Experiment cxxxv. Charge the jar as before, then touch the wire which is connected with the negative side, and the opposite wire will throw off a diverging cone; but if the positive side is touched, a luminous cone will only be seen on the other wire.

Experiment cxxxvi. *Fig*. 53 is an electric jar; B B, the tin-foil coating; C, a stand which supports the jar; D, a socket of metal which carries the glass rod, E; a curved metallic wire, pointed at each end, is fixed to the end of the rod G, which rod is moveable at pleasure in a spring tube, N; that tube being fixed by a socket upon the top of the glass rod E, the charging wire communicates with the different divisions of the inside coating of the jar by horizontal wires.

Place the jar as usual, and put the machine in action, a small luminous spark will appear upon the upper point of the wire F, a plain indication that the point is then receiving electricity from the upper ring of the coating on the outside of the jar; a fine stream or pencil of rays will at the same time fly off, beautifully diverging from the lower point of the wire, F, upon the bottom ring of the coating on the jar; when these appearances cease, which they will as soon as the jar is charged, let a pointed wire be presented towards the prime conductor, this will soon discharge the jar silently, during which the lower point will be illuminated with a small spark, while the upper point of the wire will throw off a pencil of rays, diverging towards the upper ring of the coating.

EXPERIMENT CXXXVII. Take a Leyden jar, the neck of which should not be very broad, set the coating on the conductor, and charge it negatively; when charged, if not too dry, the upper edge of the coating will throw off one or more brushes of light into the air, which will visibly incline towards the charging wire of the jar, and sometimes actually reach it. Present the knob to the prime conductor, and charge the jar positively; a small spark of light will first appear on the edge of the cork in the neck of the bottle through which the wire passes, after a few turns of the cylinder; this spark becomes a brush, darting out from the cork, and gradually lengthening till it forms an arch, the end of it extending downwards till it reaches and touches the end of the coating. If the jar be dry, it will in both cases be discharged spontaneously. See *fig.* 54 and 55.

EXPERIMENT CXXXVIII. An insulated positively charged jar will give a spark from its knob to an excited stick of wax, while no spark will pass between it and an excited glass tube.

EXPERIMENT CXXXIX. *An analysis of the Leyden jar, by means of the Leyden vacuum,* E, *fig.* 49. Screw this on the insulated stand, with the pointed wire from the bottom. *Fig.* 56 represents the appearance of the fluid on the points when the jar is charged negatively, at a conductor loaded with positive electricity.

Fig. 57, the appearances it displays when it is charging positively at the same conductor.

Fig. 59, *plate* 4, is the same jar charging positively at a negative conductor. *Fig.* 60, it is charging negatively at the same conductor.

EXPERIMENT CXL. *Fig.* 61 represents the luminous conductor on the insulating stand. Set the collecting point near the cylinder, and place the knob of an uncharged jar in contact with the ball, or hang a chain from it to the table, and on working the machine, the ball will be enveloped in a dense electric atmosphere. If the point be brought in contact with an insulated rubber, and a communication is made from the ball to the table, the atmosphere will be on the point in the tube. If a jar positively charged be presented, the appearances in the tube will be as delineated in *fig.* 62. But, if a jar negatively charged be thus applied, the appearance will be as in *fig.* 61.

This tube, when mounted on its insulating stand, may be used instead of the prime conductor, and all the common experiments may be performed with it. The tube will be luminous during the whole of the operation.

OF THE DIRECTION OF THE ELECTRIC MATTER IN THE DISCHARGE OF THE LEYDEN JAR.

EXPERIMENT CXLI. Place a charged jar on a small glass stand under the receiver of an air-pump; as the receiver is exhausting, the electric fire will issue from the wire of the jar, in a very luminous pencil of rays, and continue flashing to the coating till the air is exhausted, when the jar will be found to be discharged.

If the jar is charged negatively, the current of fire will appear to have a different direction from that which it had before.

From this experiment we may infer the effects of the atmospheric pressure upon the charge of the Leyden jar, and learning that it is the natural boundary to every charge of electricity we can give; and, consequently, that a jar would contain double the charge, in air doubly condensed, as it does in the common atmosphere, since it would increase the intensity of the electric atmosphere.

Experiment cxlii. Place a small lighted taper between the two balls of the universal discharger, then pass a very small charge of a positive jar through them, and the flame of the taper will be attracted in the direction of the fluid towards the coating. See *fig*. 63.

Experiment cxliii. The same small charge from a negative jar will reverse the appearance.

In both these experiments it is necessary to use the least charge that can be given, just sufficient to leap the interruption in the circuit.

Experiment cxliv. Place a card on the table of the universal discharger, and bring one of the points under the card, then connect this point with the coating of a jar positively charged; place the other point on the top of the card, and at about an inch and an half from the former row complete the circuit, by bringing a discharging rod from the last wire to the top of a jar, and the electricity will pass through the upper wire, along the surface of the card, till it comes to the point which is underneath, where it will make a hole in the card, and pass through the wire to the coating of the jar. See *fig*. 64.

Experiment cxlv. Four cork balls, A, B, C, D, being placed at equal distances from each other, from the balls of the discharging rod, and from the coating of a positively charged jar; on making the discharge, the ball A next the rod was repelled to B, which was again repelled to C, C remained immoveable, and D flew to the coating of the jar.

Experinent cxlvi. Take a card, and paint both sides with cinnabar about the breadth of the finger, fix this card vertically by a little wax on the table of the universal discharger, let the pointed end of one of the wires touch one side of the card, and the end of the other wire the opposite side; the distance of the points from each other must be proportioned to the strength of the charge: discharge a jar through the wires, and the black mark left by the explosion on the coloured band, shews that the electric fluid passed from the wire communicating with the inside of the jar to that which communicates with the outside, against which it makes a hole.

EXPERIMENTS WHICH SEEM TO MILITATE AGAINST THE RECEIVED THEORY OF ELECTRICITY.

EXPERIMENT CXLVII .Let the surfaces of an electric plate be very slightly charged and insulated, let an interrupted circuit be formed, the two powers will be visible, illuminating the points of the interrupted circuits, and each power will appear to extend further from the surface contiguous to it, the stronger the charge that is communicated to the plate; but, if the illuminations on each side meet, there will immediately follow an explosion of the whole charge. The length of the interrupted circuit used for this experiment was twelve feet.*

EXPERIMENT CXLVIII. If a cylindrical plate of air, contained in the receiver of an air-pump, be charged, it is observed, the more air that is exhausted from between the surfaces, the more easily the powers will unite.

EXPERIMENT CXLIX. If an exhausted receiver be made part of the electric circuit, and the charge should not be sufficient to cause an explosion, an electric light will appear to proceed

* *Atwood's* Analysis of a Course of Lectures, p. 121.

in an opposite direction from the parts communicating with the negative and positive surfaces.

EXPERIMENT CL. Let a coated jar be set on an insulating stand, and let its knob be touched by the knob of another jar negatively electrified; a small spark will be seen between them, and both sides of the insulated jar will be instantly negatively electrified.*

Fasten a pith ball electrometer by a little wax to the outside coating of a jar, charge the jar slightly with positive electricity, and set it on an insulated stand, the ball will either not diverge, or only a very little; bring the knob of a jar, which is strongly charged with positive electricity, near the knob of the former, and the balls will diverge with positive electricity.

EXPERIMENT CLI. Let the same jar, with the pith balls affixed to its outside coating, be slightly charged negatively, and then insulated, bring the knob of a jar, which is strongly electrified negatively, to that of the insulated one, and the pith balls will diverge with negative electricity.

EXPERIMENT CLII. Charge a jar positively, and then insulate it; charge another strongly with negative electricity, bring the knob of the negative jar near that of the positive one, and a thread will play between them; but, when the knobs

* Encyclopædia Britannica, vol. iv. p. 2698.

touch each other, the threads, after being attracted, will be repelled by both. The negative electricity is some how superinduced on the positive, and for a few minutes after they are separated, both will appear negatively electrified; but if the finger is brought near the knob of that jar on which the negative electricity was superinduced, it will instantly be dissipated, a small spark will strike the finger, and the jar will be positively charged as before.

Some of the positions which support the Franklinian hypothesis have been already considered; we are now at a proper stage for pointing out those deficiencies which have been observed in other parts of it. To support this hypothesis, it is necessary to maintain, *that glass, and other electric substances, though they contain a great deal of electric matter, are nevertheless impermeable to it.*

This position appears contradictory at the first view; for it is not easy to conceive, that any substance can be full of a fluid, and yet impermeable by it; especially when a considerable quantity of this fluid is taken from one side and added to the other: and, what is more surprizing, the thinner the glass, and the less quantity it is capable of containing, the more we are able to put into it, and the stronger will be the charge.*

* Encyclopædia Britannica, p. 2687.

The following, among other experiments, has been adduced as a strong argument in favour of the impermeability of glass. Let a coated jar be set upon an insulated stand, and the knob of another coated jar be brought near it; for every spark discharged from the prime conductor to the knob of the first jar, a spark will pass from the coating of the first to the knob of the second: now, a common observer generally imagines that the fire runs through the glass; Dr. *Franklin* concludes it does not, because there is found a great accumulation of electricity on the inside of the jar, which manifests itself when the inside and outside are made to communicate with each other. But, we cannot from this and similar experiments conclude that glass is impermeable, except we suppose the electric matter to be accumulated on one side of the glass, and deficient on the other; but this has never yet been proved: it has indeed been said, that if glass were permeable to this fluid, it could never be charged; but this rests wholly on the supposition that there is an accumulation of the fluid in bodies positively electrified, and a deficiency in those which are negatively so.*

Mr. *Wilson*, to prove the permeability of glass, took a very large pane of glass a little warmed;

* Encyclopædia Britannica, p. 2687.

and, holding it upright by one edge, while the opposite edge rested upon wax, he rubbed the middle part of the surface with his finger, and found both sides electrified *plus*; he accounted for this from the electric fluid passing through the glass from his finger. But Dr. *Priestley* says, this appearance ought to take place on Dr. *Franklin*'s principles; for, the fire given to the glass by the finger on one side, repels an equal quantity from the other, which stands as an atmosphere, so that both sides appear positively electrified. Mr. *Wilson* tried also another experiment, which seems more decisive than the former. Having by him a pane of glass, one side of which was rough and the other smooth, he rubbed it on one side; upon doing this, both sides were electrified *minus*. Dr. *Priestley* attempts to reconcile this to Dr. *Franklin*'s hypothesis; as the electric fluid contained in glass, says he, was kept equal on both sides by the commom repulsion. If the quantity on one side is diminished, the fluid on the other side being less repelled retired inward, and leaves that surface *minus*. But surely those words militate strongly against the system he means to establish. The quantity of fluid in one side being diminished, that on the other, he says, *retires inward*. But into what does it retire? If into the substance of the glass, then is the glass permeable by it, which is the very thing Dr. *Priestley* argues against.*

DR. GREY ON THE FRANKLINIAN EXPLANATION OF THE LEYDEN JAR.

Dr. *Franklin*, in various parts of the first volume of his experiments and observations, asserts, that the natural quantity of electric fluid in glass cannot be increased or decreased; and, that it is impossible to add any to one surface of a plate or jar, unless an equal quantity be at the same time given out from the other surface. This error has been adopted by succeeding electricians; among others, by the late Mr. *Henley*, who, in one of his last papers printed in the Philosophical Transactions for the year 1777, has the following words: "According to Dr. *Franklin*'s theory, the same quantity of electric matter which is thrown upon one of the surfaces of glass, in the operation of charging it, is at the same time repelled or driven out from the other surface; and thus one of the surfaces becomes charged *plus*, the other *minus*; and that this is really the case, is, I think, satisfactorily proved," &c.

Beccaria also has adopted the same opinion, saying, that a quantity of excessive fire cannot be

* Encyclopædia Britannica, p. 2688.

introduced into one surface, but in as much as an equal dose of natural fire can quit the other surface.

These assertions are, I apprehend, directly contrary to what really happens; instead of which, I believe, we may safely assert, that glass, and every other known substance, may have its natural quantity of electric fluid either increased or diminished to a certain limited degree; which degree bears no proportion to the quantity of matter contained in a body, but is, *cæteris paribus,* in proportion to the extent of its surface.

This law, which is perhaps without exception, may be considered as one of the fundamental laws of electricity, and one upon which many of its principal phenomena depend. At present, I shall only consider it so far, as it is the cause of what is commonly called the charge of a coated jar: suppose such a jar insulated, and connected by its knob to the prime conductor of an electrical machine, if then the machine be put in action, a certain quantity of electric fluid, agreeable to the above-mentioned law, is added to the natural quantity belonging to the inner surface of the jar. After which, if the finger, or any other conducting substance, be presented to the outer coating of the jar, a quantity of electric fluid, nearly equal to that thrown in, comes from it. But, this departure of the electric fluid from the outside of the jar, cannot be, as Dr. *Franklin* supposes it, the cause which permits the addition of fluid to the inside, but is merely the consequence of the action of that superfluous quantity which was thrown in; and the operator may, if he pleases, instead of taking the electric fluid from the outside of the jar, take out again, by touching the knob, nearly the whole of what he had thrown in, which he could not do, if an equal quantity had already gone from the outside of the jar. When the quantity already spoken of has been taken from the outside of the jar, the equilibrium being nearly restored, another quantity like the first may again be added to the inner surface; after which a similar quantity may again be taken from the outside; thus, by the succession of a sufficient number of the quantities allowed by the forementioned law, the jar may at length be completely charged.

There are other ways of charging coated glass; but if it be allowed that the charge, in the foregoing instance, is produced in the manner I have supposed, it will not, I think, be disputed that all other charges are produced by a similar alternation of small quantities; this, however, will appear more clear from the following observations on the manner in which the discharge is produced.

When the astonishing velocity with which the charge of a jar or battery moves through a considerable space is considered, it may at first appear impossible, that the discharge should be made by the alternate giving and receiving such small quantities as those by which the charge was produced; yet, a more ample consideration of the matter will, I think, shew that it cannot possibly be brought about any other way.

I presume it will be granted, that the charge of a jar, in discharging, either leaves it all at once, or goes out in the same small quantities by which it went in. To suppose any intermediate manner, would neither lessen the difficulty, nor would it be consonant to any of the known laws of electricity.

If then the whole charge leave the jar all at once, there must be a point of time at which the jar will be without any electric fluid, either on one side or the other; nay more, suppose a large jar or battery to be discharged by means of a few inches of thin wire, there will then be a point of time at which the whole quantity of electric fluid, which constituted the charge, must be contained in a piece of wire, weighing only a few grains.

Now, if it be considered, that time, like matter, is infinitely divisible, may we not rather suppose, that the discharge of a jar is nothing more than an inconceivable rapid succession of such small quantities as may be sent off, without causing such a destruction of the equilibrium as the laws of electricity seem not to admit.* To this we may add from other experiments, that one side of a charged electric may contain more of one power than is sufficient to balance the contrary power on the other side. For, if a charged jar is insulated, and the discharge is made by a discharger with a glass handle, after the explosion, the discharger and both sides of the jar will possess a contrary power to that obtained on the side of the jar which was touched the last before the discharge.

A DESCRIPTION OF A VERY PORTABLE OR POCKET ELECTRICAL APPARATUS, BY THE EDITOR.

Various substances, besides glass, have been used by electricians for the excitation or collection of the electric fluid: in a large machine, glass has decidedly the preference; for a small apparatus, resin, lack, baked wood, silk, brown paper, &c. Dr. *Ingenhouz*, who many years ago invented the glass plate machine, contrived a portable apparatus for charging a small phial by

* Dr. *Grey*'s paper, Philos. Trans. part 1st, 1788.

means of a varnished silk ribbon exposed to the friction of a rubber attached to the external coating, while the opposite electricity of the silk was taken off by a metallic part communicating with the inside. With some small variation, I have constructed this apparatus, and made it capable of a tolerable strong charge or accumulation of electricity, and to give a small shock to one, two, three, or a greater number of persons.

Plate 5, *fig*. 99, A is the small Leyden phial or jar that holds the charge; B is the discharger, to discharge the jar, when required, without electrifying the person that holds it; C is a varnished ribbon to be excited, and communicate its electricity to the jar; D are two hare, &c. skin rubbers, which are to be placed on the first and middle fingers of the left hand.

To charge the jar. Place the two finger-caps, D, on the first and middle finger of the left hand; hold the jar, A, at the same time at the edge of the coating on the outside, between the thumb and first finger of the same hand; then take the ribbon in your right hand, and steadily and gently draw it upwards between the two rubbers, D, on the two fingers, taking care at the same time the brass ball of the jar is kept nearly close to the ribbon, while it is passing through the fingers. By repeating this operation twelve or fourteen times, the electrical fire will pass into the jar, which will become charged, and by placing the discharger, C, against it, as shewn in the figure, you will see a sensible spark pass from the ball of the jar to that of the discharger. If the apparatus is dry and in good order, you will hear the crakling of the fire when the ribbon is passing through the fingers, and the jar will discharge at the distance represented in the figure.

To electrify a person. You must desire him to take the jar in one hand, and with the other touch the knob of it; or, if diversion is intended, desire the person to smell at the knob of it, in expectation of smelling the scent of a rose or a pink; this last mode has occasioned it sometimes to be called the *magic smelling bottle.*

Mr. *Cavallo* describes a still more simple apparatus for producing the electric charge, though not so portable as the above, which he calls the *self charging Leyden phial,* and thus describes:

"Take a glass tube of about eighteen inches in length, and an inch, or an inch and an half, in diameter. It is immaterial whether one of its ends be closed or not. Coat the inside of it with tin-foil, but only from one open extremity of it to about as far as its middle; the other part, which remains uncoated, we shall call the naked part of the instrument. Put a cork to the aperture of the coated end, and let a knobbed wire pass through the cork, and come in contact with the coating. The instrument being thus prepared, hold it in one hand by the naked part, and with the other hand clean and dry-rub the outside of the coated part of the tube; but, after every three or four strokes, you must remove the rubbing hand, and must touch the knob of the wire, and in so doing a little spark will be drawn from it. By this means, the coated end of the tube will gradually acquire a charge, which may be increased to a considerable degree. If then you grasp the outside of the coated end of the tube with one hand, and touch the knob of the wire with the other hand, you will obtain a shock, &c.

" In this experiment, the coated part of the tube answers the double office of electrical machine and of Leyden phial; the naked part of it being only a sort of handle to hold the instrument by. The friction on the outside of the tube accumulates a quantity of positive electricity upon it, and this electricity in virtue of its sphere of action, forces out of the inside a quantity of electricity also positive. Then by taking the spark from the knob, this inside electricity, which is by the coating communicated to the knob through the wire, is removed, consequently the inside remains under-charged or negative, and of course, the positive electricity of the outside comes closer to the surface of the glass, and begins to form the charge. By farther rubbing and taking the spark from the knob, this charge is increased, &c.

" Instead of a tube, this instrument may be constructed with a pane of glass; in which case it will be rather simpler, but it cannot be managed so easily, nor of course can it be charged so high as the tube. A piece of tin-foil must be pasted in the middle of only one surface of the pane, leaving about two inches and an half or three inches of uncoated glass all round. This done, hold the glass by a corner, with the coated side from you, and with the other hand rub its uncoated side, and take the spark from the tin-foil alternately, until you think that the glass may be sufficiently charged; then lay the glass with its uncoated side flat upon one open hand, and, on touching the tin-foil with the other hand, you will receive the shock."

The electric power of a charged jar may be conveyed to any distance, and its effects have been found to be instantaneous in going through a conducting wire of several miles, which connected the two coatings of a jar; but it is somewhat weakened by the length of the circuit.

For mere entertainment, a person might be electrified at the door of a room or house. A chain or wire connected with the outside coating of a jar should secretly go along the floor, under the door, and lay on the ground close to the outside of the door, another chain or wire fastened at one end to the knob of the lock, and at the other end to an insulated wire or director. Then, at the instant of the person's attempting to open the door by his hand at the knob, the discharge of the jar is to be made by bringing the insulated wire to the ball of the jar; the fire will pass from the jar, along the wire, to the hand of the person, and through him, to his feet and the wire on the ground communicating with the outside of the jar; and thus giving him the shock.

Electricity has been thought of as the means of conveying a very quick intelligence from one place to another. For this purpose Mr. *Cavallo* has made several experiments, and from which probably some use may de derived. The best means he found was by inflammable air; and the following is his description of the method which he found to succeed best, and by which means gunpowder or other combustibles may be certainly fired from the distance of two or three hundred feet; and probably from a much greater distance, without danger to the operator, or without any loss of time; for the inflammation will take place at the moment that the knob of the charged jar is presented to the extremity of the long wire.

" The inflammable air must be contained in a two or three ounce phial, such as is used for medicines, which must be prepared in the following manner: Turn the phial with the bottom upwards, and by striking the apex of the conical cavity with a pointed thick wire, a hole will be made in the bottom of the phial. In this hole a piece of thin wire must be cemented, so as to project about an inch within the phial, and its external part must be bent in the form of a hook. A very sound cork must be fitted to the mouth of the phial, and another piece of thin wire must be passed through it, so as to project within the phial, and to come with its extremity to the distance of about the fortieth part of an inch from the extremity of the wire that proceeds from the bottom. The external part of this wire in the cork should be about two or three feet in length. The phial being thus prepared, remove the cork from it, and place it inverted for about four or five seconds of time, over the mouth of another large phial full of inflammable air; then slip it off, and cork it up as fast as you can. By this means a certain quantity of inflammable air will be introduced, which, by mixing with the common air contained in the phial, will form a compound elastic fluid, which is so ready to take fire, that, if the least electric spark be passed from wire to wire through the phial, the air will instantly explode, and the cork will be pushed out of it with violence. The long wire of communication is prepared in the following manner:

"A piece of annealed copper or brass wire, of about a fiftieth or fortieth part of an inch in diameter, being stretched from one side of a room to the other, heat it successively from one end to the other by means of the flame of a candle, or of a red-hot piece of iron; and, as you proceed with the candle, rub a lump of pitch over the heated part of the wire. When the wire has been thus covered with pitch, a slip of linen rag must be put round it, which can be easily made to adhere to the pitch, and over this rag another coat of pitch must be laid with a brush, the pitch being melted in a pipkin or other convenient vessel. This second layer of pitch must be covered with a slip of woolen cloth, which must be fastened by means of a needle and thread. Lastly, the cloth must be covered with a thick coat of oil paint, and when the paint is dry, the covered wire may be used for the experiment. In this manner many pieces of wire, each of about twenty or thirty feet in length, may be prepared, which may afterwards be joined together, so as to form one continued metallic communication; but care must be taken to secure the places where the pieces are joined, which is most readily done by wrapping a piece of oil-silk over the painted cloth, round the two contiguous extremities, and binding it with thread. When a long wire has been thus made out of the various short pieces, let one end of it, purposely left out beyond the fore-mentioned envelopes, be formed into a ring, and to the other extremity adapt a small brass ball.

" In order to perform the experiment, lay the wire upon the ground in any direction, fasten the hooked wire of the phial that contains the inflammable air to the ring at one end of it, and push the extremity of the wire that comes out of the cork of the said phial about an inch or two into the ground. Then, if you bring the knob of a charged Leyden phial in contact with the ball at the other extremity of the long wire, the inflammable air will explode immediately, and the cork will be pushed out of the neck of the phial.

" For this purpose a Leyden phial, that contains about one square foot of coated surface, will be found to be quite sufficient, when the distance between the operator and the spot in which the inflammation is to take place does not exceed 200 feet. For greater distances it will be necessary to use Leyden jars of proportionably larger size.

" Thus we have shewn how inflammable air may be fired; but, in order to set fire to gun-powder, the only addition which needs be made, is to surround the cork and neck of the phial with loose cotton, that has been previously filled with pounded gun-powder, from which a quick match may be continued, &c. for, when the cork is pushed out of the neck of the phial by the explosion of the inflammable air, a flame comes out which has power sufficient to set fire to the gun-powder in the cotton. I have sometimes put a small quantity of cotton rubbed in gun-powder into the phial of inflammable air, besides the cotton on the outside; but it is by no means necessary.

" The only inconvenience which I have found to attend the above-described method is, that sometimes the very nature of the inflammable air in the phial suffers such an alteration as to lose its inflammability; in which case the experiment will not be attended with the desired effect. But this degeneration of the inflammable air does seldom, if ever, take place in less than two or three days, and sometimes not even in a fortnight; so that one may be sure that the experiment will answer within 24 or 30 hours; and it is probable that it will answer within two or three days. It is immaterial whether the phial be left attached to the long wire on the ground all that time, or be fastened to it the moment before the time of inflammation.

" If this experiment be tried without any inflammable air in the phial, the only effect will be, that a spark will be seen between the two wires in the phial at the moment that the charged jar is applied to the knobbed end of the long wire. By sending a number of sparks at different intervals of time, according to a settled plan, any sort of intelligence might be conveyed instantaneously from the place in which the operator stands to the other place in which the phial is situated. With respect to the greatest distance to which such communication might be extended, I can only say, that I never tried the experiment with a wire of communication longer than about 250 feet; but, from the results of those experiments, and from the analogy of other facts, I am led to believe that the fore-mentioned sort of communication might be extended to two or three miles, and probably to a much greater distance."*

* *Cavallo* on Electricity, vol. iii. p. 285, et seq.

CHAP. XI.

OF THE ELECTRICAL BATTERY, AND THE LATERAL EXPLOSION OF CHARGED JARS.

To increase the force of the electric explosion, several Leyden jars are connected together in a box; this collection is termed an electrical battery. *Fig.* 65 represents one of the most approved form.

The bottom of the box is covered with tin-foil, to connect the exterior coatings; the inside coatings of the jars are connected by the wires a, b, c, d, e, f, which meet in the large ball A; C is a hook at the bottom of the box, by which any substance may be connected with the outside coating of the jars; a ball, B, proceeds from the inside, by which the circuit may be conveniently completed. The following precautions are necessary to be attended to by those who make use of an electrical battery.

To keep the top and uncoated part of the jars dry and free from dust; and, after the explosion, to connect a wire from the hook to the ball, which should be left there till the battery is to be charged again, which will totally obviate the inconveniences that have occasionally happened from the residuum of a charge.

If one jar in a battery is broke, it is impossible to charge the rest till the broken jar is removed.*

To prevent the jars of a large battery breaking at the time of the explosion, it has been recommended not to discharge a battery through a good conductor, except the circuit is at least five feet long; but what is gained on one hand by this method, is lost on the other; for, by lengthening the circuit, the force of the shock is weakened proportionably.

I have been informed, that it is very difficult to break by an explosion the jars which are made of green glass, fabricated at Newcastle, but have had no opportunity to make any experiments on this glass myself.

The force of a battery may be considerably increased by concentrating the spark from the explosion, which is effected by causing it to pass through small circuits of non-conducting substances. By this means the resisting medium, through which the spark is to pass, may be so prepared as to augment its power. If the spark is made to pass through a hole in a plate of glass,

* A cracked jar may be made to receive a charge, by taking away the external and internal coatings which were over the crack, so as to leave a space of about one-fourth of an inch between the crack an remaining tin-foil.

one-twelfth or one-sixth part of an inch in diameter, it will be less dissipated, more compact and powerful. If the part round the hole is wetted with a little water, the spark, by converting this into vapour, may be conveyed to a greater distance, with an increase of rapidity, attended with a louder noise than common.

Mr. *Morgan*, by attending to these, and some other circumstances, has melted wires, &c. with small jars.

EXPERIMENT CLIII. *To make wire red hot.* Pass the charge of a strong battery through two or three inches of small wire, it will sometimes appear red-hot, first at the positive side, and the redness will proceed regularly towards the other end.

EXPERIMENT CLIV. *To perforate paper.* Discharge a battery through a quire of paper, a perforation will be made through it; each of the leaves is protruded by the stroke from the middle towards the outward leaves, as if the fire darted both ways from the center. If the paper is very dry, the fire meets with more difficulty in its passage, and the hole is small. If that part of the paper, through which the explosion is made, is wet, the hole is larger, the light more vivid, and the explosion louder.

EXPERIMENT CLV. *To give the magnetic power.* The discharge of a battery through a small steel needle will, if the charge is sufficient, communicate magnetism to the needle.

EXPERIMENT CLVI. *To invert the magnetic poles.* The discharge of a battery through a small and slender magnetic needle, will generally destroy the polarity of the needle, and sometimes invert the poles thereof. To succeed in this experiment, it is often necessary to pass several strong charges through the needle, before it is removed from the circuit.

It appears from *Beccaria*'s experiments, that the magnetic polarity, which is communicated to the needle by electricity, depends on the position of the needle when the charge is sent through it, and is not regulated by the direction of the electric matter in entering the needle.

EXPERIMENT CLVII. *Atwood on electric perforation.* Let a quire of paper be suspended by a line in the manner of a pendulum from any convenient altitude, so that its plane may be vertical. Let the largest charge from a battery be caused to pass through it, while quiescent in an horizontal direction perpendicular to the plane, the rods of communication not touching the paper. The phenomena are, first, the aperture heretofore mentioned, the leaves being protruded both ways from the middle: second, not the smallest motion is communicated to the paper from the force of the discharge.

A quire of the thickest and strongest paper was made use of for this experiment; the height from which it was suspended, sixteen feet. It is an extraordinary appearance on the hypothesis of a single electric fluid, that a force, sufficient to penetrate a solid substance of great tenacity and cohesive force, should not communicate the smallest motion to the paper, when a breath of air would cause some sensible vibration in it. But this difficulty is not unanswerable: for a velocity may be assigned, with which a body impinges against and passes through a pendulum of any given weight and resisting force, so that a smaller angular velocity shall be communicated to it, than any that shall be proposed; and we know no limit to the velocity of the electric power or powers. But the other phenomenon, *i. e.* the opposite direction in which the leaves are protruded, tends very much to strengthen the opinion of two opposite currents. Perhaps either of those phenomena, considered simply, may admit of an easy solution from the hypothesis of a single power; when they are taken both together, it seems more difficult to reconcile this hypothesis with matter of fact.*

EXPERIMENT CLVIII. *To melt a wire.* Discharge a battery through a slender piece of wire,

* *Atwood*'s Analysis.

ex. gr. one-fiftieth of an inch in diameter, the wire will be broken to pieces or melted, so as to fall on the table in glowing balls.

When the wire is melted in this manner, the sparks fly frequently to a considerable distance, being scattered by the explosion in all directions.

If the force of the battery is very great, the wire will be entirely dispersed by the force of the explosion. Small particles of such substances as cannot be easily drawn into wire, as platina, grain gold, ores, &c. may be placed in a groove of wax, and then put into the circuit; if a discharge of sufficient strength is passed through them, they will be melted.

The force, by which wires are melted by a battery, varies with the length of the circuit, as the fluid meets with more resistance in proportion as the passage through which it is to pass is longer. Dr. *Priestley* could melt nine inches of small iron wire at the distance of fifteen feet, but at twenty feet distance he could only make six inches of it red-hot; so that metals resist with considerable force the passage of the electric fluid, and therefore in estimating the conducting powers of different substances, their length must be particularly attended to.

Experiment clix. Inclose a very slender wire in a glass tube, discharge a battery through this wire, and it will be thrown into globules of different sizes, which may be collected from the inner surface of the tube: they are often found to be hollow, and little more than the scoria of the metal.

Many experiments have been made, in order to try the different conducting powers of metals, by passing the discharge of a battery through them; but it has not yet been determined, whether the greater facility with which some metals are exploded depends on the ease with which the fluid passes through them, or whether it proceeds from the degree of resistance they make to its passage, or from a want of ductility in the metal, which is therefore less capable of expansion.

EXPERIMENT CLX. Discharge a battery through a chain which is laid on paper, and black marks will be left on the paper in those places where the rings of the chain touch each other; the rings will be more or less melted at those places.

EXPERIMENT CLXI. *To stain glass.* Take two pieces of window glass, of about three by two inches; place a slip of brass or gold leaf between them, leaving the metallic leaf out beyond the glass at each end; then place the two pieces of glass in the press of the universal discharger, *pl.* 2, *fig.* 3, bring the points of the wires E T, E F, to touch the ends of the leaves, and pass a discharge through them, which will force part of the metal into the glass, and stain it with a colour which differs from the metal that is made use of. The metallic leaf should be made narrowest in the middle, because the force of the electric fire is in proportion to its density, which is increased when the same quantity of fire is compelled to pass through fewer conducting particles.

The explosion in melting the strips of leaf-gold, &c. renders them non-conducting and less capable after each discharge to transmit another. Some particles of the metal are driven into the glass, which is really melted; those parts of the metal which lie contiguous to the glass, are the most perfectly fused. The pieces of glass which cover the slip of metal are generally broken to pieces by the discharge.

Experiment clxii. *To break thick pieces of glass.* Place a thick piece of glass on the ivory plate of the universal discharger, *plate* 2, *fig.* 3, and a thick piece of ivory on the glass, on which a weight from one to seven pounds is to be placed; bring the points of the wires, E F, E T, against the edge of the glass, and pass the discharge through the wires, by connecting one of the wires, as E F, with the hook, C, of the battery, *plate* 4, *fig.* 65, and forming a communication, when the battery is charged, from the other wire, E T, to the ball, and the glass will be broken, and some part of it shivered to an impalpable powder. When the piece of glass is strong enough to resist the shock, the glass is often marked by the explosion with the most lively and beautiful colours. I have been informed by Mr. *Morgan*, that if the glass is cemented down, the effect is the same as when it is pressed by the weights; and this mode is in various experiments more convenient.

Place a piece of very dry white wood between the balls of the universal discharger, the fibres of the wood to be in the same direction with the wires, pass the shock through them, and the wood will be torn to pieces; or run the points into the wood, and then pass the shock through them.

Experiment clxiii. *To raise weights.* If the discharge is passed under the piece of ivory with the weights upon it, without any glass between the piece of ivory and the table, G H, of the universal discharger, the weights will be lifted up by the lateral force of the discharge: the number of weights must be proportioned to the force of the explosion.

Experiment clxiv. *Lateral explosion. Pl.* 4, *fig*. 66, *a* represents an insulated rod, nearly touching a charged jar; *b* is another insulated rod, placed in a line with and near to the former; make the discharge by the rod *c*, from which a chain hangs that does not touch the bottom of the jar, and the rod, *b*, will receive an electric spark, which quits it again almost in the same instant, because the finest threads hung upon it will not be electrified by the spark.

This electrical appearance, without the circuit of a discharging jar, is called the *lateral explosion.*

If pieces of cork, or any light bodies, be placed near the explosion of a jar or battery, they will be moved out of their place in all directions from the center of the explosion; and the greater the force of the explosion, so much greater will the distance be to which they are removed. It is not surprizing, therefore, that heavy bodies should be removed to considerable distances by a strong flash of lightning. Dr. *Priestley* apprehends, that this species of lateral force is produced by the explosion of the air from the place through which the electric discharge passes.

This lateral force is not only exerted in the neighbourhood of an explosion, when it is made between pieces of metal in the open air, but also when it is transmitted through pieces of wire that are not thick enough to conduct it perfectly. The smaller the wire is, and the greater the fusion, the greater is the dispersion of light bodies near it.

EXPERIMENT CLXV. *Course of lateral explosion.* If circuits, different in length and of different substances, form a communication between two charged surfaces of an electric plate, it is observed, the discharge will be made through the best conductors, whatever be the length of the others.

2. If circuits of the same substance be different in length, the discharge will be made through the shortest of them.

3. If the circuits be the same in every respect, the discharge will be made through many of them at the same time.*

If one circuit consists of undried wood, and is of considerable length in comparison of another which consists of metal, the discharge will be made wholly through the latter, unless the charge should be very great, in which case some small part will pass through the wood.

If a short metallic rod and any part of the human body form two circuits between the same charged surfaces, the discharge will, in general, be made wholly through the metallic rod; but if the charge is very great, or if the rod is very slender, or if it should be very long, in either of these cases the discharge may be perceived to pass through that part of the body which forms one of the circuits.

This will be the case when the charge is small; but it may be so increased, as to pass through both the longer and shorter circuits.

* *Atwood*'s Analysis, p. 119, 120.

I have been informed by a gentleman, that it was his custom to make a variety of circuits for the discharge of a large jar or battery; and, that having a sufficient number of these, he could introduce himself into one of them, and take his part of the shock without inconvenience—it even was not disagreeable; and he could by this means lessen the sensation almost to nothing.

Experiment clxvi. Mr. *Henley* made a double circuit, the first by an iron bar, one inch and an half in diameter, and half an inch thick; the second, by four feet and an half of small chain. On discharging a jar, containing five hundred square inches of coated surface, the electricity passed in both circuits, sparks being visible on the small chain in many places. On making the discharge of three jars, containing together sixteen square feet of coated surface, through three different chains at the same time, bright sparks were visible in them all. The chains were of iron and brass, of very different lengths; the shortest ten or twelve inches, the longest many feet in length. When those jars were discharged through the iron bar beforementioned, together with a small chain, three-quarters of a yard in length, the whole chain was illumined, and covered throughout with beautiful rays, like bristles or golden hair. Having placed a large jar in contact with the prime conductor, he affixed to the coating of it an iron chain, which was also connected with a plate of metal, on which was made the discharge by the discharging rod: this done, he hooked another chain, much longer and of brass, to the opposite side of the jar, and brought the end of it within eight inches and an half of the metal plate. In contact with this end a small oak stick was laid, eight inches long, which was covered with saw-dust of fire wood. On making the discharge upon the plate, both the chains were luminous through their whole lengths, as was also the saw-dust, which was covered by a streak of light, making a very pleasing appearance.

At the glass-house there is generally made a number of rods of glass, about one-quarter of an inch diameter; if these be examined narrowly, several of them will be found tubular a considerable length; the diameter of the cavity seldom exceeds the 200th part of an inch. Select and break off the tubular part, which may be filled with quicksilver by sucking, care being taken that no moisture previously insinuates itself; the tube will then be prepared for the experiment.

Experiment CLXVII. *Displosion of mercury.* Pass the shock through this small thread of quicksilver, which will be instantly disploded, and will break or split the tube in a curious manner.*

* *Nicholson*'s Introduction to Philosophy, p. 413.

Experiment clxviii. Take a glass tube, the bore of which is about one-quarter of an inch, fill it with water, and stop the ends with cork, insert two wires through the corks into the tube, so that their ends may nearly touch, make the ends of these part of a circuit from a battery; on the discharge, the water will be dispersed in every direction, and the tube blown to pieces by the discharge.

The electric fluid, like common fire, converts the water into an highly elastic vapour. Dr. *Franklin*, on repeating this experiment with ink, could not find the least stain upon the white paper on which the tube had been placed. *Beccaria* passed the shock through a drop of water, which was supported in the center of a solid glass ball between the ends of two iron wires, and the ball was shivered in pieces by the explosion. On this principle he contrived what he calls an electrical mortar, which will throw a small leaden ball to the distance of twenty feet. It is clear, from several of the foregoing experiments, that the electric fluid endeavours to explode, in every direction, the parts of the resisting substances through which it passes.

Experiment clxix. *Electric earthquake.* Place a building, which is formed of several loose pieces of wood, on a wet board in the middle of a large bason of water, let the electric flash from a battery be made to pass over the board, or over the water, or over both; the water will be strongly agitated, and the building thrown down. The report is louder than when the explosion passes only through the air.

The electric fluid endeavours to pass near the surface of the water, where it meets with more resistance than if it is forced to pass through it. This partly arises from the power the electric fluid has of raising an expansive vapour from the surface of the water, which drives off the resisting air.

A discharge passed over the surface of a piece of ice, will leave on it small unequal cavities, exhibiting the same appearance as if a hot chain had been placed on it.

A discharge sent through a green leaf tears the surface in various directions, leaving an image in miniature of some of the effects of lightning. A discharge will pass to a certain distance over spirit of wine, without inflaming it; but, if the distance is increased, it will set it on fire. From hence it appears, that the facility with which the electric fire is transmitted over the surfaces of moist substances, depends on the ease with which they are turned into vapours.

The discharge, in melting the particles of metals, drives into its passage the conducting vapours which arise from them; and in proportion as the parts of any body are more readily driven into vapour or dust, the spark will run to a greater distance.

EXPERIMENT CLXX. *Wire lengthened.* If a wire is stretched by weights, and a shock is sent through it that will render it red-hot, it is found to be considerably lengthened after the discharge. When the wire is loose, it is said to be shortened by the explosion.*

EXPERIMENT CLXXI. If a long narrow trough of water is made part of the circuit in the discharge of a battery, and a person's hand be immerged in the water at the time of the explosion, he will feel an odd vibration in the water, very different from an electrical shock. The quick

* The explosion of steel wire has been found to be the best method of measuring electricity. Mr. *Cuthbertson* from a variety and succession of experiments has proved, that the quantity of electricity to disperse a given portion of wire will be the same, even though the charged surface should be greatly varied; or, that equal quantities of electricity in the form of a charge will cause equal lengths of the same steel wire to explode, whether the jar made use of be of greater or less capacity. The kind of jar made use of, was a common one with *Lane*'s electrometer, its balls being at a fixed distance, as shewn at *a b*, *plate* 5, *fig.* 86; the wire was of steel flattened, such as used for the spring of the balance in watches, about $\frac{1}{5000}$ of an inch in breadth. The jar with the electrometer was applied to the conductor; a brass ball, supported on an insulated stand, was placed so as to receive the explosion from the jar: from this ball hung a small piece of the above wire, confined at each end between small forceps, and the length of the wire five inches. Gradual increases of the interval or length of spark were made, till the charge became so strong as completely to ignite the wire. The length of the explosive spark was $\frac{1}{4}$ inch. See *Nicholson*'s Journal, vol. ii. p. 217.

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stroke from the re-percussion of the air and the vapour is communicated to the hand by the water, and the hand receives a shock similar to that received by a ship at sea during an earthquake.

EXPERIMENT CLXXII. *Prismatic rings.* Place a plain piece of metal between the points of the universal discharger, pass several explosions of a battery through the wires, and the discharges will gradually form on the metal different circles, beautifully tinged with the prismatic colours. The circles appear sooner, and are closer to each other, the nearer the point is to the surface of the metal. The number of rings or circles depend on the sharpness of the point; the experiment therefore succeeds better if a sharp needle is fastened to one of the points of the discharger.

Several very curious experiments were made by Dr. *Watson* and others, to ascertain the distance to which the electric shock might be conveyed, and the velocity with which it moves. In this first experiment, the shock was given and spirits fired by the electric matter which had been conveyed through the river Thames. In the next experiment, the electric fluid was made to pass through a circuit of two miles, crossing the New-river twice, going over several gravel-pits, and a large field. It was afterwards conveyed through a circuit of four miles. It passed over these spaces instantaneously as to sense. This sensible instantaneity in the motion of the electric fluid was ascertained by an observer, who, though in the room with the charged jar, was at the same time in the middle of a circuit of two miles, and felt himself shocked at the same instant he saw the jar discharged.

Notwithstanding this surprizing velocity, it is certain that both sides of a charged jar may be touched so quickly, even by the best conductors, that all the electric matter has not time to make the circuit, and the jar will remain but half discharged; and there are several instances where the motion appears slow, and not easily reconcileable with this immeasurable velocity; and it is also certain, that this fluid is resisted in its passage through or over every substance.

The wonderful part of the foregoing experiments will vanish, if we admit the reasoning of Dr. *Gray* and Mr. *Volta* on this subject; and the reader will find this reasoning considerably strengthened by experiments of Mr. *Atwood*, related in this Essay, though it must be owned, these experiments seem to lead much further, and give an idea of the direction of the electric fluid in the discharge of the Leyden jar, which differs altogether from the received theory.

CHAP. XII.

ON THE DIFFUSION AND SUBDIVISIONS OF FLUIDS BY ELECTRICITY.

WE are chiefly indebted to *Abbe Nollet* for what is known on the subject of this chapter, which was investigated by him with incredible industry and patience. I have only subjoined the principal result of his experiments, and must refer the reader, for a more ample account, to the Abbe's own writings, or Dr. *Priestley*'s History of Electricity.

Electricity augments the natural evaporation of fluids; since, excepting mercury and oil, all the others which were tried suffered a diminution that could not be ascribed to any other cause than electricity.

It increases the evaporation of those fluids most, which naturally tend to evaporate readily. Volatile spirits of sal-ammoniac lost more than spirit of wine, this more than water, &c.

Electricity acts strongest upon the fluids, when the vessels which contain them are non-electrics. The evaporation was greatest in the most open vessels, but did not increase in proportion to their apertures. It does not make any liquor evaporate through the pores either of metal or glass.

To extend these principles further, the Abbe made a great variety of experiments on electrified capillary tubes, and found that the stream would be sub-divided; but it is not sensibly accelerated, if the tube is not less than one-tenth of an inch diameter in the inside.

Under this diameter, if the tube is wide enough to let the fluid run in a stream, electricity will accelerate its motion in a small degree.

If the tube is so far capillary, that the water only issues from it in drops, the electrified jet becomes a continued stream; it will even be divided into several smaller ones, and its motion is considerably accelerated; the smaller the diameter of the tube, the greater is the acceleration. When the surface is wider than one-tenth of an inch, electricity seems rather to retard the motion of the fluid.

From some very accurate experiments made by M. *de Saussure* with his new hygrometer, it appears that the foregoing theory, which asserts that electricity always promotes evaporation, is only true under certain restrictions. It increases the evaporation from those bodies which are supersaturated, but does not occasion any evaporation in those which do not contain a superabounding quantity of water.

EXPERIMENT CLXXIII. *Electrical jet d'eau.* *Fig.* 77 represents a metal phial, to which a capillary tube is adapted, which will only permit water to pass through it in interrupted drops. Fill the pail with water, and suspend it from the prime conductor, then turn the cylinder, and the water will pass through the tube in a continued stream; this will separate into other streams, that will appear luminous in the dark.

EXPERIMENT CLXXIV. Suspend one pail from a positive conductor, and another from a negative one, so that the ends of the tubes may be about three or four inches from each other, and the stream proceeding from one will be attracted by that which issues from the other, and form one stream, which will be luminous in the dark.

If the pails are suspended on two positive or two negative conductors, the streams will recede from each other.

EXPERIMENT CLXXV. *Electrical stream of water.* Place a metal bason on an insulating stand, and connect it with the prime conductor; then pour a small stream of water into the bason, which in the dark will have a beautiful appearance, as the stream will be divided into a great number of lucid drops.

EXPERIMENT CLXXVI. *Electrified sponge.* Dip a sponge in water, and then suspend it from the conductor; the water, which before only dropped from it, will now fall fast, and appear in the dark like fiery rain.

EXPERIMENT CLXXVII. *Contrary effects of electricity in forming jet d'eaus.* Hold a pail, which is furnished with several capillary tubes placed in various directions, near an electrified conductor, and the water will stream out of those jets near the conductor, while it will only drop at intervals from those which are opposite to it.

EXPERIMENT CLXXVIII. *Conical drop of water.* The knob of a charged jar will attract a drop of water from a saucer, &c. This drop, the moment the jar is removed from the saucer, assumes a conical shape, and if it is brought near any conducting substance, it is driven forcibly away in small streams, which are luminous in the dark.

It appears by this experiment, that the electric fire not only tends to separate the particles of water, and to dissipate them into vapour as common fire, but that it effects this with uncommon rapidity.

EXPERIMENT CLXXIX. *Discharge a battery through a drop of water,* previously placed on the knob of one of its jars; the whole will be instantly exploded into vapour; the sparks will be much longer than common, and more compact.

Beccaria observes, that by sending a discharge to a greater or less distance, through one or more drops of quicksilver, the discharge diffuses itself into drops, and drives them into vapour; part of it rising into the air in the form of smoke, the other part remains on the glass.

EXPERIMENT CLXXX. *A drop of water hanging from the condensing ball of an electrified conductor*, will stretch towards water placed in a cup under it, lengthening and shortening itself according to the force of the electricity.

EXPERIMENT CLXXXI. *Zig-zag sparks from a drop of water.* Place a drop of water on the prime conductor, turn the machine, and long zig-zag sparks may be taken from it; the drop will take a conical figure, the body that receives the spark will be wetted, and the spark will be considerably longer than can be obtained from the conductor without the water.*

EXPERIMENT CLXXXII. *Threads spun from wax.* Stick a piece of sealing-wax on the conductor, in such a manner that it may be easily set on fire by a taper; while it is flaming turn the cylinder, the wax will become pointed and shoot out an almost invisible thread into the air, to the length of a yard or more. If the filaments that are thrown out by the wax are received on a sheet of paper, the paper will be covered by them in a very curious manner, and the particles of the wax

* *Nicholson's* Introduction to Philosophy.

will be so far subdivided as to resemble fine cotton. To fasten the piece of wax conveniently to the conductor, stick it first on a small piece of paper, then twist the end of the paper so as to fit one of the holes which are made in the prime conductor; when it is thus placed, it may be readily fired by a taper.

EXPERIMENT CLXXXIII. *Electrical fountain.* Insulate a fountain made by condensed air, and which emits only one stream; electrify the fountain, and the stream will be separated into a great number; these will diffuse themselves equally over a large space of ground. By laying a finger upon the conductor, and taking it off again, the operator may command either the single stream or the divided one, at pleasure.

EXPERIMENT CLXXXIV. *Electrify two small insulated fountains* with the different electric powers; the streams of both will be dispersed into very minute particles, which will run together at the top, and come down in heavy drops, like a shower of rain.

CHAP. XIII.

OF THE ELECTRIC LIGHT IN VACUO.

EXPERIMENT CLXXXV.

Take a tall dry receiver, and insert in the top with cement a wire with a rounded end, then exhaust the receiver, and present the knob of the wire to the conductor, and every spark will pass through the vacuum in a broad stream of light visible the whole length of the receiver, moving with regularity, unless it is solicited and bent out of its way by some non-electric, then dividing itself into a variety of beautiful rivulets, which are continually dividing and uniting in a most pleasing manner. If the vessel is grasped by the hand, at every spark a pulsation is felt, like that of an artery, and the fire bends itself towards the hand. This pulsation is even felt at some distance from the receiver, and in the dark a light is seen between the hands and the glass. The streams of light pass silently through the receiver, because the air is removed, by whose vibration sound is produced.

From some experiments made several years since by Mr. *Wilson*, with an excellent air-pump of Mr. *Smeaton*, he observed that very small differences of air occasioned very material differences in the luminous effects produced by the electric fluid; for, when all the air was taken out of the receiver, which this pump at that time was capable of extracting, no electric light was visible in the dark. Upon letting in a little air by a stop-cock, a faint electric light was visible; and, by letting in a little more air, increased the light, which again decreased on letting in more air; till at last, on admitting great quantities, it entirely vanished. By this experiment it appeared, that a certain limited quantity of air was necessary to occasion the greatest luminous effect.

Experiment clxxxvi. *No repulsive power in the particles of electricity. Fig.* 82 represents an exhausted receiver standing on the plate of an air-pump; *a b*, an electrified wire discharging a stream, *b c*, of the electric fluid on the plate of the air-pump. If the stratum of air on the outside of the receiver be lessened by the application of the finger to the receiver, and by this means an opportunity be given to the fluid on the outside to escape, the fluid within will be impelled to that part, as at *d e f*.

It has been inferred from this experiment, that no repulsive power exists between the particles of the electric fluid; because, if it was in itself really elastic, or endowed with a repulsive power of its own, it is not probable it could pass in an uninterrupted stream, as at *b c*, when the resistance was taken off; it would then spread wider, and display its elastic power.

It is more consistent, says Dr. *Watson*, to suppose that the repulsion of these particles, which is seen in the open air, is occasioned by the resistance of the air, and not by any natural tendency of the electricity itself.

By considering the experiments made with the electric fluid *in vacuo*, we attain a clear idea of the resistance the air continually makes to its passage, and see that the divergence of its rays is not to be attributed to an imaginary repulsion, but to the resistance of the ambient air; for the divergence ceases and the rays unite, when this resistance is removed.

EXPERIMENT CLXXXVII. Before the air was exhausted from the receiver, if the wire at the top of it was electrified, a diverging brush proceeded from it about an inch long, but little of the fluid passing off, and even that little requiring a strong impulsive force to push it forward. On exhausting the receiver, the following changes took place: first, the rays of the brush became longer; secondly, the rays diverged less, were fewer in number, and the size of the remaining rays was increased; thirdly, they all united at last, and formed a continued column of light, from the wire to the plate of the air-pump.

From this experiment it is clear, that the air is the agent by which, with the assistance of other electrics, we are able to communicate electricity to electrics, as well as non-electrics; for, when this is removed, the fluid pervades the vacuum, and flies off to a considerable distance.

EXPERIMENT CLXXXVIII. *To distinguish with great accuracy the changes in the form and length of the electric spark when it is passing through a receiver, the air of which is more or less rarefied.* Fix a ball to the rod, let another proceed from the plate of the air-pump; the balls are to be placed about one inch from each other. When the vacuum is good, a single uniform ray of a purple colour passes from one ball to the other; but in proportion as the air is admitted, the ray acquires a quivering motion, which indicates that a resistance to its motion then begins, and this interruption is followed by a division of the ray or stream; the ray now acquires a more vivid light; and, lastly, it becomes the common spark, which is emitted with greater or less facility, in proportion to the power of the machine and the resistance of the air.

EXPERIMENT CLXXXIX. *Aurora borealis.* Present a thin exhausted flask similar to that represented at E, *fig*. 49, but without any coating on the outside, to the conductor, and the jar will be luminous from end to end; and, when taken from the conductor, will continue luminous, moving in various curvilinear directions for a considerable time, flashing at intervals in a manner which very much resembles the Aurora Borealis. The light may be revived, by passing the flask through the hand. The stroke of the fluid against the glass is very sensibly heard and felt in this experiment.

The flexuous motions of the electric fluid in an exhausted receiver may, in some degree, be produced at pleasure. By wetting the outside of the receiver, the fire will follow the direction of the wetted line, as the resistance is now lessened on one side; and the fire can adhere and accumulate itself on the inside of the receiver, because, by means of the dampness, it can expel a portion from the outside.

This experiment may be exhibited very pleasingly, by making a Torricellian vacuum in a glass tube about three feet long, and then sealed hermetically. Hold one end of this tube in the hand, and apply the other to the conductor, and immediately the whole tube will be illuminated from end to end, and will continue so for a considerable time after it is removed from the conductor, flashing at intervals for many hours.

EXPERIMENT CXC. *Luminous jets of fire.* Screw on a ball, of about an inch diameter, to the rod of the plate of the collar of leather of an air-pump; place this on a tall receiver; connect the exterior part of the rod with the conductor; place some cylindrical pieces of metal on the plate of the pump; then exhaust the receiver in part, and electrify the rod at intervals, and luminous jets of fire, like fulminating meteors, will fly from the ball to the cylinders of metal.

EXPERIMENT CXCI. Another beautiful appearance may be produced in the dark, by inserting a small Leyden jar into the neck of a tall receiver, so that the outward coating may be exposed to the vacuum. Exhaust the receiver, and then charge the jar, and at every spark which passes from the conductor to the inside, a flash of light is seen to dart from every part of the external surface of the jar, so as to fill the receiver. Upon making the discharge, the light is seen to return in a close body.

EXPERIMENT CXCII. *Electrified barometer.* A very perfect vacuum for the passage of the electric fluid may be made by a double barometer, or long bent tube of glass filled with mercury and inverted, each leg standing in a bason of mercury; the bent part of the tube above the mercury forms a complete vacuum. If a jar is discharged through this space, the light appears uniform through the whole space, but is most vivid when the discharges are strong. Dr. *Watson* insulated this apparatus, and then made one of the basons of mercury communicate with the conductor, and touched the other with a non-electric; the electric fluid pervaded the vacuum in a continued flame, without any divergence; when one of the basons was connected with the insulated cushion, the fire appeared to pervade the vacuum in a different direction.

EXPERIMENT CXCIII. *Fig.* 83 represents a glass tube, such as is generally used for barometers; on the end, *b*, a steel cap is cemented, from which a wire and ball, *c d*, proceed into the tube. Fill this tube with quicksilver, and then, by sending up a large bubble of air, and repeatedly inverting the tube, free the quicksilver and iron ball from air, according to the ordinary mode of filling barometers; then place a small drop of ether on the quicksilver, and put the finger on the end of the glass tube, and insert the end, *f*, in a bason of quicksilver, taking care not to remove the finger from the end of the tube, till the end is immerged half an inch under the silver. When the finger is removed, the quicksilver will descend, and the ether will expand itself, lessen the vacuum, and depress the mercury in the tube: now present the metallic top of the tube to a large charged conductor, and a beautiful green spark will pass from the ball to the quicksilver. By admitting a small quantity of air into the vacuum, an appearance something similar to a falling star is obtained.

EXPERIMENT CXCIV. *Cavallo on electric appearances in vacuo.* Place the brass cap of a well exhausted receiver at about half an inch from the prime conductor, so that when the machine is in action, sparks may pass from the conductor to the brass cap of the receiver. Mr. *Cavallo*, in relating the circumstances attending an experiment of this kind made by him, observes, that when the receiver was exhausted, the spark passed from the cap to the plate of the pump through the receiver, illuminating its whole cavity; that the vacuum became a better conductor of electricity in proportion as it was more perfect, and that the electric light was more equally diffused, but it was by no means faint when the receiver was exhausted to the utmost. The light changed according as the receiver was more or less exhausted. The appearances were as follow:

DEGREE OF RAREFACTION, AS SHEWN BY THE GAGE.	APPEARANCES OF THE ELECTRIC LIGHT WITHIN THE RECEIVER.
Air rarefied 40 times,	Light in large, long, but divided streams.
70	Fine diffused light of a white colour.
80 100 400	Beautiful diffused light inclining to a red or purple, and filling the whole receiver.
When the gage shewed the utmost degree of exhaustion,	A diffused light filled equally the receiver; it had hardly any reddish hue.*

See also Experiments 112, 113, 121, 122, of this Essay, for further observations on the appearance of the electric light *in vacuo.*

EXPERIMENTS ON ELECTRIC LIGHT, BY MR. WILLIAM MORGAN.

1. There is no fluid or solid body, in its passage through which the electric fluid may not be made luminous; in water, spirit, oil, animal fluids of all

* Phil. Trans. vol. lxxiii. part ii. p. 451.

kinds, the discharge of a Leyden jar of almost any size will appear very splendid, provided we take care to place them in the circuit, so that the fluid may not pass through too great a quantity of them. The general method is, to place the fluid on which the experiment is to be made, in a tube three quarters of an inch in diameter and four inches long; stop up the orifices of the tube with two corks, through which push two pointed wires, so that the points may approach within one-eighth of an inch to each other; the fluid, in passing through the interval which separates the wires, is always luminous, if a force be used sufficiently strong; the glass tube, if not very thick, always breaks when this experiment succeeds. To make the passage of the fluids luminous in the acids, they must be placed in capillary tubes, and two wires introduced, as in the preceding experiment, whose points shall be very near each other. It is a well-known fact, that the discharge of a small Leyden jar, in passing over a strip of gold, silver, or Dutch metal leaf, will appear very luminous. By conveying the contents of a jar, measuring two gallons, over a strip of gold leaf one-eighth of an inch in diameter and a yard long, it will frequently give the whole a dazzling brightness. We may give this experiment a curious diversity, by laying the gold or silver leaf on a piece of glass, and then placing the glass in water; for the whole gold leaf will appear most brilliantly luminous in the water, by exposing it thus circumstanced to the explosion of a battery.

2. The difficulty of making any quantity of the electric fluid luminous in any body, increases as the conducting power of that body increases.

In order to make the contents of a jar luminous in boiling water, a much higher charge is necessary than would be sufficient to make it luminous in cold water, which is universally allowed to be the worst conductor.

There are various reasons for believing the acids to be very good conductors; if, therefore, into a tube filled with water, and circumstanced as has been already described, a few drops of either of the mineral acids are poured, it will be almost impossible to make the fluid luminous in its passage through the tube.

If a string, whose diameter is one-eighth of an inch, and whose length is six or eight inches, is moistened with water, the contents of a jar will pass through it luminously; but no such appearance can be produced by any charge of the same jar, provided the same string be moistened with one of the mineral acids. To the preceding instance we may add the various instances of metals, which will conduct the electrical fluid without any appearance of light, in circumstances the same with those in which the same force would have appeared luminous in passing through other bodies, whose conducting power is less.

3. That the ease with which the electrical fluid is rendered luminous in any particular body, is increased by increasing the rarity of the body. The appearance of a spark, or of the discharge of a Leyden jar in rarefied air, is well known. But we need not rest the truth of the preceding observation on the several varieties of this fact; similar phenomena attend the rarefaction of ether, of spirit of wine, and of water.

EXPERIMENT CXCV. *Spark in rarefied water, spirit of wine, ether, and acids.* Into the orifice of a tube, 48 inches long, and two-thirds of an inch in diameter, cement an iron ball, so as to bear the weight which presses upon it when the tube is filled with quicksilver, leaving only an interval at the open end, which contained a few drops of water. Having inverted the tube, and plunged the open end of it into a bason of mercury, the mercury in the tube stood nearly half an inch lower than it did in a barometer at the same instant, owing to the vapour which was formed by the water. But through this rarefied water, the electrical spark passed as luminously as it does through air equally rarefied.

If, instead of water, a few drops of spirit of wine are placed on the surface of the mercury, phenomena similar to those of the preceding experiment will be discovered, with this difference only, that as the vapour in this case is more dense, the electrical spark in its passage through it is not quite so luminous as it is in the vapour of water.

Good ether, substituted in the room of the spirit of wine, will press the mercury down so low as the height of 16 or 17 inches. The electrical fluid in passing through this vapour, unless the force be very great indeed, is scarcely luminous; but, if the pressure on the surface of the mercury in the bason be gradually lessened by the aid of an air-pump, the vapour will become more and more rare, and the electric spark, in passing through it, more and more luminous.

It has not been discovered, that any vapour does escape from the mineral acids when exposed *in vacuo*; to give them therefore greater rarity or tenuity, different methods are found necessary. With a fine camel-hair pencil dipped in the vitriolic, the nitrous, or the marine acid, draw upon a piece of glass a line about one-eighth of an inch broad; in some instances you must extend this line to the length of 27 inches, and you will find that the contents of an electric battery, consisting of ten pint jars coated, will pass over the whole length of this line with the greatest brilliancy. If, by widening the line or by laying on a drop of the acid, its quantity be increased in any particular part, the charge in passing through that part will not appear luminous. Water or spirit of wine, circumstanced similarly to the acids in the preceding experiments, will be attended with similar, but not equal effects; because, in consequence of the inferiority of their conducting power, it will be necessary to make the line through which the charge passes considerably shorter.

4. The brilliancy or splendor of the electric fluid, in its passage through any body, is always increased by lessening the dimensions of that body; that is, a spark, or the discharge of a battery, which we might suppose equal to a sphere one-quarter of an inch in diameter, will appear much more brilliant if the same quantity of fluid is compressed into a sphere one-eighth of an inch in diameter. This observation is the obvious consequence of many known facts; if the machine be large enough to afford a spark whose length is nine or ten inches, this spark may be seen sometimes forming itself into a brush, in which state it occupies more room but appears very faintly luminous; at other times, the same spark may be seen dividing itself into a variety of ramifications, which shoot into the surrounding air. In this case likewise, the fluid is diffused over a large surface, and in proportion to the extent of that surface, so is the faintness of the appearance. A spark, which in the open air cannot exceed one-quarter of an inch in diameter,

will appear to fill the whole of an exhausted receiver four inches wide and eight inches long: but, in the former case it is brilliant, and in the latter it grows fainter and fainter, as the size of the receiver increases. This observation is further proved by the following experiments.

EXPERIMENT CXCVI. To an insulated ball four inches in diameter, fix a silver thread about four yards long. This thread, at the end which is remotest from the ball, must be fixed to another insulated substance. Bring the ball within the striking distance of a conductor, and the spark, in passing from the conductor to the ball, will appear very brilliant; the whole length of the silver thread will be faintly luminous at the same instant. When the spark is confined within the dimensions of a sphere one-eighth of an inch in diameter, it will be bright; but when diffused over the surface of air which received it from the thread, its light will be so faint as to be seen only in a dark room. If you lessen the surface of air which receives the spark, by shortening the thread, it will not fail to increase the brightness of the appearance.

EXPERIMENT CXCVII. To prove that the faintness of the electric light *in vacuo* depends on the enlarged dimensions of the space through which it is diffused, we have nothing more to do than to introduce two pointed wires into the vacuum, so that the fluid may pass from the point of the one to the point of the other; when the distance between them is not more than the one-tenth of an inch, in this case we shall find a brilliancy as great as in the open air.

Experiment cxcviii. Into a Torricellian vacuum, 36 inches long, convey as much air as will fill two inches only of the exhausted tube, if it were inverted in water; this quantity of air will afford resistance enough to condense the fluid, as it passes through the tube, into a spark 38 inches in length. The brilliancy of the spark in condensed air, in water, and in all substances through which it passes with difficulty, depends on principles similar to those which account for the preceding facts.

5. That, in the appearances of electricity, as well as in those of burning bodies, there are cases in which all the rays of light do not escape; and that the most refrangible rays are those which escape first or most easily. The electrical brush is always of a purple or bluish hue. If you convey a spark through a Torricellian vacuum, made without boiling the mercury in the tube, the brush will display the indigo rays. The spark however may be divided and weakened, even in the open air, so as to yield the most refrangible rays only.

Experiment cxcix. To an insulated metallic ball four inches in diameter, fix a wire a foot and an half long; this wire should terminate in four ramifications, each of which must be fixed to a metallic ball half an inch in diameter, and placed at an equal distance from a metallic plate, which must be communicated by metallic conductors with the ground. A powerful spark, after falling on the large ball at one extremity of the wire, will be divided in its passage from the four small balls to the metallic plate. When you examine the division of the fluid in a dark room, you will discover some little ramifications, which will yield the indigo rays only: indeed, at the edges of all weak sparks the same purple appearance may be discovered. You may likewise observe, that the nearer you approach the center of the spark, the greater is the brilliancy of its colour.

6. That the influence of different media on electrical light, is analogous to their influence on solar light, and will help us to account for some very singular appearances.

Experiment cc. Let a pointed wire, having a metallic ball fixed to one end of its extremities, be forced obliquely into a piece of wood, so as to make a small angle with the surface of the wood, and to make the point lie about one-eighth of an inch below the surface; let another pointed wire which communicates with the ground, be forced in the same manner into the same wood, so that its point likewise may lie about one-eighth of an inch below the surface, and about two inches distant from the point of the first wire. Let the wood be insulated, and a strong spark, which strikes on the metallic ball, will force its passage through the interval of wood which lies between the points, and appear as red as blood. To prove that this appearance depends on the wood's absorption of all the rays but the red; when these points were deepest below the surface, the red only came to the eye through a prism; when they were raised a little nearer the surface, the red and orange appeared; when nearer still, the yellow; and so on, till by making the spark pass through the wood very near its surface, all the rays were at length able to reach the eye. If the points be only one-eighth of an inch below the surface of soft deal wood, the red, the orange, and the yellow rays will appear, as the spark passes through it; but, when the points are at an equal depth in a harder piece of wood, such as box, the yellow, and perhaps the orange, will disappear. As a farther proof that the phenomena thus described are owing to the interposition of the wood, as a medium which absorbs some of the rays, and suffers others to escape, it may be observed, that when the spark strikes very brilliantly on one side of the piece of deal, on the other side it will appear very red. In like manner, a red appearance may be given to a spark which strikes brilliantly over the inside of a tube, merely by spreading some pitch very thinly over the outside of the same tube.

EXPERIMENT CCI. If into a Torricellian vacuum of any length a few drops of ether are conveyed, and both ends of the vacuum are stopped up with metallic conductors, so that a spark may pass through it; the spark in its passage will assume the following appearances: when the eye is placed close to the tube, the spark will appear perfectly white; if the eye is removed to the distance of six or seven yards, the colour of the spark will be reddish. These changes evidently depend on the quantity of medium through which the light passes, and the red light of a distant candle or beclouded sun.

EXPERIMENT CCII. Dr. *Priestley* long ago observed the red appearance of the spark when passing through inflammable air; but this appearance is very much diversified by the quantity of medium through which you look at the spark; when at a very considerable distance, the red comes to the eye unmixed; but if the eye is placed close to the tube, the spark appears white and brilliant. In confirmation, however, of some of these conclusions, you must observe, that by increasing the quantity of fluid which is conveyed through any portion of inflammable air, or by condensing that air, the spark may be entirely deprived of its red appearance, and made perfectly brilliant. All weak explosions and sparks, when viewed at a distance, bear a reddish hue. Such are the explosions which have passed through water, spirit of wine, or any bad conductor, when confined in a tube whose diameter is not more than an inch. The reason of these appearances seem to be, that the weaker the spark or explosion is, the less is the light which escapes, and the more visible the effect of any medium, which has a power to absorb some of that light.

Chalk, oyster-shells, together with those phosphoric bodies, whose goodness has been very much impaired by long keeping, when finely powdered, and placed within the circuit of an electrical battery, will exhibit by their scattered particles a shower of light; but these particles will appear reddish, or their phosphoric power will be sufficient only to detain the yellow, orange, and red rays. When spirit of wine is in a similar manner brought within the circuit of a battery, a similar effect may be discovered; its particles diverge in several directions, displaying a most beautiful golden appearance. The metallic calces are, of all bodies, those which are rendered phosphoric with the greatest difficulty; but even these may be scattered into a shower of red luminous particles by the electric stroke.

ELECTRICAL EXPERIMENTS, MADE IN ORDER TO ASCERTAIN THE NON-CONDUCTING POWER OF A PERFECT VACUUM, &c. BY MR. WILLIAM MORGAN.

The non-conducting power of a perfect vacuum is a fact in electricity which has been much controverted among philosophers. The experiments made by Mr. *Walsh*, F. R. S. in the double barometer tube, clearly demonstrated the impermeability of the electric light through a vacuum; nor was it, I think, precipitate to conclude from them the impermeability of the electric fluid itself. But this conclusion has not been universally admitted, and the following experiments were made with the view of determining its truth or fallacy.

A mercurial gage, B, *plate* 1, *fig.* 14, about fifteen inches long, carefully and accurately boiled till every particle of air was expelled from the inside, was coated with tin-foil five inches down from its sealed end, A, and being inverted into mercury through a perforation, D, in the brass cap, E, which covered the mouth of the cistern, H, the whole was cemented together, and the air was exhausted from the inside of the cistern through a valve, C, in the brass cap, E, just mentioned;

which, producing a perfect vacuum in the gage, B, afforded an instrument peculiarly well adapted for experiments of this kind. Things being thus adjusted, a small wire, F, having been previously fixed on the inside of the cistern, to form a communication between the brass cap, E, and the mercury, G, into which the gage was inverted, the coated end, A, was applied to the conductor of an electrical machine; and, notwithstanding every effort, neither the smallest ray of light nor the slightest charge could ever be procured in this exhausted gage. It is well known, that if a glass tube be exhausted by an air-pump, and coated on the outside, both light and charge may very readily be procured. If the mercury in the gage be imperfectly boiled, the experiment will not succeed; but the colour of the electric light, which in air rarefied by an exhauster is always violet or purple, appears in this case of a beautiful green; and, what is very curious, the degree of the air's rarefaction may be nearly determined by this means. There have been instances known in a course of experiments, where a small particle of air having found its way into the tube, B, the electric light became visible, and, as usual, of a green colour; but, the charge being often repeated, the gage has at length cracked at its sealed end, and in consequence the external air, by being admitted into the inside, has gradually produced a change in the electric light, from green to blue, from blue to indigo, and so on to violet and purple, till the medium has at last become so dense, as no longer to be a conductor of electricity. There can be little doubt, from the above experiments, of the non-conducting power of a perfect vacuum; and this fact is still more strongly confirmed by the phenomena which appear upon the admission of a very minute particle of air into the inside of the gage. In this case, the whole becomes immediately luminous upon the slightest application of electricity, and a charge takes place, which continues to grow more and more powerful, in proportion as fresh air is admitted, till the density of the conducting medium arrives at its maximum, which it always does when the colour of the electric light is indigo or violet, under these circumstances, the charge may be so far increased, as frequently to break the glass. In some tubes which have not been completely boiled they will not conduct the electric fluid, when the mercury is fallen very low in them; yet, upon letting air into the cistern H, so that the mercury shall rise in the gage B, the electric fluid, which was before latent in the inside, shall now become visible, and, as the mercury continues to rise, and of consequence the medium is rendered less rare, the light shall grow more and more visible, and the gage shall at last be charged, notwithstanding it has not been near an electrical machine for two or three days. This seems to prove, that there is a limit even in the rarefaction of air, which sets bounds to its conducting power; or, in other words, that the particles of air may be so far separated from each other, as no longer to be able to transmit the electric fluid; that if they are brought within a certain distance of each other, their conducting power begins, and continually increases, till their approach also arrives at its limit; when the particles again become so near, as to resist the particles of the fluid entirely without employing violence, which is the case in common and condensed air, but more particularly in the latter.

It is surprizing to observe, how readily an exhausted tube is charged with electricity. By placing it at ten or twelve inches from the conductor, the light may be seen pervading its inside, and as strong a charge may sometimes be procured, as if it were in contact with the conductor. Nor does it signify how narrow the bore of the glass may be; for, even a thermometer tube, having the minutest perforation possible, will charge with the utmost facility; and in this experiment the phenomena are peculiarly beautiful.

Let one end of a thermometer tube be sealed hermetically; let the other end be cemented into a brass cap with a valve, or into a brass cock, so that it may be fitted to the plate of an air-pump:

when it is exhausted, let the sealed end be applied to the conductor of an electrical machine, while the other end is either held in the hand, or connected to the floor. Upon the slightest excitation, the electric fluid will accumulate at the sealed end, and be discharged through the inside in the form of a spark; and this accumulation and discharge may be incessantly repeated, till the tube is broken. By this means, a spark 42 inches long may be procured; and, if a proper tube could be found, we might have a spark three or four times that length: if, instead of the sealed end, a bulb be blown at the extremity of the tube, the electric light will fill the whole of that bulb, and then pass through the tube in the form of a brilliant spark, as in the foregoing experiment; though in this case the charge, after a few trials, will make a small perforation in the bulb. If, again, a thermometer filled with mercury be inverted into a cistern, and the air exhausted in the manner before described for making the experiment with the gage, the Torricellian vacuum will be produced; and now the electric light in the bulb, as well as the spark in the tube, will be of a vivid green; but the bulb will not bear a frequent repetition of charges, before it is perforated in like manner as when it has been exhausted by an air-pump. It can hardly be necessary to observe, that in these cases the electric fluid assumes the appearance of a spark,* from the narrowness of the passage through which it forces its way. If a tube 40 inches long be fixed into a globe eight or nine inches in diameter, and the whole be exhausted, the electric fluid, after passing in the form of a brilliant spark through the length of the tube, will, when it gets into the inside of the globe, expand itself in all directions, entirely filling it with a violet and purple light, and exhibiting a striking instance of the vast elasticity of the electric fluid.

Mr. *Brook*'s method of making mercurial gages is nearly as follows. Let a glass tube, L, *fig.* 15, sealed hermetically at one end, be bent into a right angle within two or three inches of the other end: at the distance of about an inch or less from the angle, let a bulb, K, of about three-quarters of an inch in diameter, be blown in the curved end, and let the remainder of this part of the tube be drawn out as to I, so as to be sufficiently long to take hold of, when the mercury is boiling. The bulb, K, is designed as a receptacle for the mercury, to prevent its boiling over, and the bent figure of the tube is adapted for its inversion into the cistern; for, by breaking off the tube at M, within one-eighth or one-fourth

* By cementing the string of a guittar into one end of a thermometer tube, a spark may be obtained, as well as if the tube had been sealed hermetically.

of an inch of the angle, the open end of the gage may be held perpendicular to the horizon, when it is dipped into the mercury in the cistern, without obliging us to bring our finger, or any other substance, into contact with the mercury in the gage, which never fails to render the instrument imperfect. It is necessary to observe, that if the tube be fourteen or fifteen inches long, it will be necessary to boil it for three or four hours; nor will it even then succeed, unless the greatest attention be paid that no bubbles of air lurk behind, which will frequently happen, if the tube be not made very dry before the mercury is put into it. If this caution be not observed, the instrument can never be made perfect.

CHAP. XIV.

ON THE INFLUENCE OF POINTED CONDUCTORS FOR BUILDINGS.

THE importance of electricity, as well as its universal agency, becomes more conspicuous in proportion as our acquaintance with it increases. We find no substance in nature which is not acted on by it, either as a conductor or non-conductor; and discover, that the surprizing phenomena of thunder and lightning owe their origin to, and are of the same nature with it. Very little progress had been made in electricity, when the analogy between the electric spark and lightning was discovered: but the sublime idea of realizing these conjectures, and proving that the fire which flashes in the sky is the same agent which explodes and gives a shock in our experiments, was given to Dr. *Franklin*; who also first suggested the utility of pointed conductors of metal, to preserve buildings from the dreadful effects of lightning; an idea which was received with general applause and approbation. Since this period, many electricians have been induced to change their opinion relative to the utility of these conductors; and among those who understand the subject well, it has been disputed, whether the preference should be given to a conductor with a pointed end, or to one which has an obtuse termination.

The experiments which have been made on this subject are very numerous; but the greater part appear to me very inconclusive, and present only a very partial view of the subject. Among these, we may reckon those in which different substances have been introduced, to represent the action of conductors on clouds; since the various substances made use of in these experiments, were cohering masses, in which they differ essentially from the clouds which float in the air. It appears also, from many instances, that lightning does not pass in one undivided track, but that neighbouring bodies carry off their share, according to their quantity and conducting power.

A pointed conductor, which communicates with the earth, has not any particular power of attracting electricity, and acts only as any other conducting substance, which does not resist the passage of the electric fluid.

It is true, that electricity passes with more ease from an electrified body to a conductor which is pointed, than to one which is flat or globular; because, in this case, the elasticity of the electric fluid and its power to break through the air are weakened by the flat surface, which acquires a contrary electricity, and compensates the diminished intensity more than a point can; the point being easily rendered negative, while the effort of the fluid to escape from the electrified body is greater than when it is opposed by a flat surface. So that it is not the particular property of a point, or flat, but the different state of the electrified body, which causes it to part with its electricity easier; and from a greater distance, when a pointed conducting substance is presented to it, than it does to a flat or globular conductor.*

The capacity of conductors to hold electricity is in proportion to the surfaces which are free or uninfluenced by a similar atmosphere; a circumstance which will more or less affect those conductors which are applied to buildings, according to the state of the clouds and their atmosphere, the time their influence has been exerted, the nature of the conducting strata of the earth, and its electric situation.

Besides, the electric powers must be separated before any body can be electrified; and the point must be in a state to give one kind of electricity, before it can receive the other. They cannot act beyond the electric atmosphere of the body to which they are presented, and their action is differently modified by the state of the air.

* See *Volta*'s paper, Phil. Trans. vol. lxxii.

Fig. 68 represents the gable end of a house, fixed vertically on the horizontal board, F G; a square hole is made in the gable end at h i, into which a piece of wood is fitted; a wire is inserted in the diagonal of this little piece; two wires are also fitted to the gable end, the lower end of one wire terminating at the upper corner of the square hole, the top of the other wire is fixed to its lower corner; the brass ball on the wire may be taken off, in order that the pointed end may be occasionally exposed to receive the explosion.

EXPERIMENT CCIII. *Thunder house.* Place a jar with its knob in contact with the conductor, connect the bottom of the jar with the hook, H; then charge the jar, and bring the ball under the conductor, and the jar will be discharged by an explosion from the conductor to the ball of the house. The wires and chain being all in connexion, the fire will be conveyed to the outside of the jar, without affecting the house; but, if the square piece of wood is placed so that the wires are not connected, but the communication cut off, the electric fluid in passing to the outside of the jar, will throw out the little piece of wood to a considerable distance by the lateral force of the explosion. See *fig*. 68.

Unscrew the ball, and let the point which is underneath be presented to the conductor, and then you will not be able to charge the jar; for, the sharp point gradually draws the fire from the conductor, and conveys it to the coating on the outside of the jar.

The prime conductor is supposed to represent a thunder cloud discharging its contents on a weather-cock, or any other metal at the top of a building. From this experiment, many have inferred, that if there is a connexion of metal to conduct the electric fluid down to the earth, the building will receive no damage; but, where the connexion is imperfect, it will strike from one part to another, and thus endanger the whole building.

ON THE INFLUENCE OF POINTS, BY MR. HENLEY.

EXPERIMENT CCIV. Mr. *Henley* affixed to the top of a glass stand a wire, three-eighths of an inch in diameter, terminated at one end by a ball three-fourths of an inch in diameter, and at the other end by a very sharp point, see *fig.* 69; round the middle of this wire hung a chain twelve inches long; he connected the chain with the coating of a charged jar, and brought the knob of it very gently towards the ball on the insulated wire, in order to observe precisely at what distance it would be discharged upon it; which constantly happened at the distance of half an inch, with a loud and full explosion. Then charging the jar, he brought it in the same gradual manner towards the point of the insulated wire, to try also at what distance it would be struck: but this, in many trials, never happened at all; the point being approached in this gradual manner, always drew off the charge imperceptibly, leaving scarce a spark in the jar.

The same gentleman connected a jar, containing 509 square inches of coated surface, with the prime conductor; see *fig*. 68. If the jar was so charged as to raise the electrometer to 60 degrees, by bringing the ball on the wire of the thunder-house to half an inch distance from that connected with the prime conductor, the jar would be discharged, and the piece in the thunder-house thrown out to a considerable distance, Using a pointed wire as a conductor to the thunder-house, instead of the knob, the charge being the same, the jar was discharged silently, though suddenly, and the piece was not thrown out.

He afterwards made a double circuit to the thunder-house; the first by a knob, the second by a sharp pointed wire, at an inch and a quarter distance from each other, but exactly the same height. The charge being the same, the knob was first brought under the prime conductor, which was half an inch above it, and followed by the point at an inch and a quarter distance, yet no explosion fell upon the ball, as the point drew off the charge silently, and the piece in the thunder-house remained unmoved.

He insulated a large jar, and connected by chains with the external coating, on one side a knob, on the other a sharp pointed wire, both being insulated and standing five inches from each other, and placed an insulated copper ball, eight inches in diameter, so as to stand exactly at half an inch distance both from the knob and the point; the jar was then charged, and the discharge made by the discharging rod on the copper ball, from whence it leaped to the knob, which was three quarters of an inch in diameter; the jar was discharged by a loud and full explosion, and the chain was very luminous.

Mr. *Henley* suspended by a silk string from one end of a wooden bar, which turned freely in an horizontal direction upon the point of a needle, a large bullock's bladder, gilded with leaf copper; the bladder was balanced by a weight at the other end of the arm, see *fig.* 71; he gave a strong spark from the knob of a charged jar to the bladder; he then presented towards it a brass ball two inches in diameter, and observed that the bladder would come towards it at the distance of three inches; and when it got within an inch, would throw off its electricity in a full spark. He then gave it another spark, and presented a pointed wire towards the bladder, which never approached to the point nor ever gave any spark, the electricity being carried off.

Experiment ccv. *Franklin's cloud.* Take two or three fine locks of cotton, fasten one of them to the conductor of a fine thread, another lock to that, and a third to the second; put the machine in action, and the locks of cotton will expand their filaments, and will extend themselves towards the table. Present a sharp point under the lowest, and it will shrink up towards the second, and this towards the first, and all together towards the prime conductor, where they will continue as long as the point remains under them.

Experiment ccvi. *Effect on a point of diverging hair.* Fasten a number of fine threads or hair to the end of the prime conductor; when the cylinder is turned, these will diverge like rays proceeding from a center: continue turning the cylinder and present a point towards one side of the conductor, and the threads on one side will hang down and lose their divergence, but those on the other side will still continue to diverge; which shews, that the power of points to draw off the electricity does not extend round the electrified body, when means are used to keep up the supply of electricity.

Fig. 72 represents an oval board three feet long and two feet broad, coated on both sides with tin-foil, and suspended by silk lines from a double hook; this turns on an axis, which is fastened to one arm of a nice balance, and counterpoised at the other arm by a weight; part of the table underneath the board is to be covered with tin-foil, and communicate to the floor by a chain.

EXPERIMENT CCVII. *Pendulous board.* Connect the pendulous board with the prime conductor by a small wire; a few turns of the machine will electrify the apparatus. When this experiment was made, the board was attracted by the table at fifteen inches distance, and discharged itself with a strong spark. The same happened to a metal ball which was placed on the table, the board approaching till it was about one inch from the ball, and then discharging itself by a spark. If a point is fixed on the board instead of a knob, the pendulous board, though it begins to approach, stops at about four or five inches from the table, and it will not approach nearer, or give a spark: a small light is seen upon the point in the dark. A Leyden jar was then connected with the prime conductor; it now requires more turns of the machine to charge the apparatus: the effect was the same as before. The counterpoise was now held, that the board might not descend till it had received a full charge; when set at liberty, it was not only attracted by, but also gave a loud explosion on the point, insomuch, that the tin-foil round it was strained by the overflowing of the fire.

EXPERIMENT CCVIII. *Atwood's experiments on points.* If an interruption is made in each of two similar circuits, which form communications between the charged surfaces of an electric plate, and if the space of air in one of the interruptions is terminated by points, and in the other by balls, the discharge will be made through the circuit of which the points make a part, although the length of the interrupted space of air is considerably greater than that in the other circuit.

Before any discharge takes place, the two powers are suspended on the opposite surfaces of the charged electric.

An electric plate may be discharged two ways, either silently in some sensible portion of time, or by explosion in an instant: in either case experiments abundantly shew, that, *cæteris paribus*, the discharge will be made through a pointed body in preference to a round termination.

When a pointed body is presented to any charged surface, a cylindrical plate of air of evanescent diameter is charged with the contrary electricities strongly attracting each other through it; and the quantity of air being so small, there will be little resistance to their union; the discharge will be made by explosion, in preference to the gradual discharge, according as the opposite surfaces (the pointed body and the surface opposed to it) are larger, as they are nearer each other, and as the charge is greater; for it will be observed, that a point, or very small spherical termination, which is in a physical sense a point, will discharge any quantity of electricity silently and gradually without explosion, while it is at a sufficient distance from the opposite charged surface; by bringing it nearer, the method of discharge will be altered, which will now be a succession of small explosions very quickly following each other. The reason of this seems to be, that, when the charged surfaces are very near, there is not sufficient time for the contrary powers to unite gradually, nor sufficient room in which they may be diffused among the surrounding air.

This is confirmed by again removing the two opposed surfaces to such a distance, that the discharge may be made gradually; in this case, if the parts of the apparatus are so disposed by any kind of contrivance, that the discharge must necessarily be made suddenly, the method of discharge will be again altered, becoming now a succession of explosions, instead of a gradual current between the opposed surfaces. This suddenness of the discharge may be effected by a proper use of interruptions in the circuit: it may also be caused by motion; if either surface be moved briskly toward the other, the explosion of the charge will be promoted.

Elevated conductors applied to buildings, as securities from the effects of lightning, will contribute to discharge the electricity from a cloud that passes over them; and a greater quantity of the discharge will pass through a pointed conductor, than through one which is terminated by a ball: but, whether the discharge will be made by a gradual current, or by explosion, will depend on the suddenness of the discharge, on the proximity of the cloud, its motion, and the quantity of the electricity contained in it. If a small cloud hangs suspended under a large cloud loaded with electric matter, pointed conductors on a building underneath will receive the discharge by explosion in preference to those termimated by balls, the small cloud forming an interruption which allows only an instant of time for the discharge. If a single electric cloud is driven with considerable velocity near to a pointed conductor, the charge may be caused to explode upon it by the motion of the charged body. In other cases, pointed conductors contribute to discharge a thunder cloud gradually without explosion.

Mr. *Wilson*'s experiments, published in the Philosophical Transactions for 1778, have contributed greatly to explain the effects of points in discharging the electric matter.

If a conical pointed body were inserted into a similar hollow cone, formed into an electrified solid, the surfaces of the two cones being equidistant, no greater discharge of the electrics would follow, than if the two conical surfaces had been plain, and opposed to each other at the same distance.

If two electric plates be charged, and a communication formed between the positive side of one and the negative side of the other, no discharge will follow, unless a communication be formed between the other two surfaces at the same time.

The natural electricity in the atmosphere is frequently discharged in this manner: two clouds being electrified with opposite powers, the surfaces of the earth immediately under them are likewise electrified with powers contrary to those in the clouds above them; and the moisture of the earth forming a communication between the two contiguous charged surfaces, whenever the two clouds meet, there will follow a discharge both of the clouds and surface on the earth opposed to them. If the earth should be dry, and consequently afford a resistance to the union of the two electricities accumulated on or under its surface, there will follow an explosion in the earth as well as the atmosphere, which will produce concussions and other phenomena which have frequently been observed to happen in dry seasons, particularly in those climates which are the most liable to storms of thunder and lightning.

DR. MUSGRAVE'S OBSERVATIONS ON POINTED CONDUCTORS.

Dr. *Franklin*, in none of the passages where he speaks of the efficacy of sharp-pointed conductors to prevent electrical explosions, has expressed any doubt of their being universally preferable for this purpose to those which have a blunt or spherical termination. The same observation may be made of the other gentlemen who are the advocates for this doctrine. It may therefore be assumed, that both he and they mean to assert an universal proposition, *That sharp points will, in all cases, draw off the electrical fluid silently within the distance at which rounded ends will explode*; *or, at least that the former sort will in no case receive an explosion at a greater distance than the latter.* Though I dissent from this doctrine, I do not mean to assert the contrary universal proposition, but only to deny the universality cf that asserted by Dr. *Franklin*, which I apprehend to be sometimes true, and sometimes also false.

But, before I attempt to specify the particular cases in which the sharp and the blunt terminations are respectively more liable to electrical explosions, it may be of use to shew, what many gentlemen seem not to be thoroughly aware of, that sharp points, having the most perfect communication with the earth, are not wholly exempt from receiving them. My first authority shall be Dr. *Franklin* himself. "Let a person," says he, p. 60, "standing on the floor, present the point of a needle of twelve or more inches from it (the prime conductor,) and while the needle is so presented, the conductor cannot be charged, the point drawing off the fire as fast as it is thrown on by the electrical globe. Let it be charged, and then present the point at the same distance, and it will *suddenly* be discharged." The word *suddenly* means, I suppose, that it will receive an explosion; that being the most natural and obvious proof of the *suddenness* of the discharge. The same thing is more directly asserted by Mr. *Henley*, in vol. lxiv. p. 138, of the Phil. Trans. where he informs us, that, in discharging three of his large jars, to the coating of which he had connected wire nicely tapered to a point, the fire flew to the point, and the jars were discharged with a full and loud explosion. A third, and equally decisive proof is furnished by Mr. *Nairne*'s experiments, though seemingly made with a contrary view. For, when the double or interrupted conductor was used, and the second conductor fixed down by screws at about three inches distance from the first, the point presented to the contrary end of the second conductor was found to receive a strong and loud explosion, with a white light, at the distance of at least three inches.

If we compare this experiment with another very common one, exhibited at the same time by Mr. *Nairne*, the comparison will perhaps lead us to the discovery of a principle upon which electrical explosions very frequently depend. Though the point, in the circumstances above-described, received so strong an explosion, yet, when it was presented directly to the prime conductor, it received no explosion whatever at any distance, unless a succession of weak sparks at the distance of about a quarter of an inch can be called so. To what must this difference be attributed? Plainly to the different quantity of electric fluid accumulated on the prime conductor in the one and the other case. Where the point is presented to the prime conductor, from the time the machine begins to work, the property which is attributed to them, and which in some cases they really possess, of stealing away the electricity silently; this property, I say, operating from the very beginning, prevents the electric fluid from being accumulated in the prime conductor, and of course the quantity of it will always be small. But, when a double or interrupted conductor is used, the second conductor receives no electricity till the prime conductor is pretty highly charged, and, if put at the greatest striking distance, not till it is fully charged, and consequently the sharp point presented to the opposite end can carry away none of it till that time; when the whole quantity is thrown off at once. It should seem then, that the explosion in one case, and the non-explosion in the other, depended wholly upon the different quantities to be thrown off: whence it will follow, that though a small quantity of electricity will pass off silently upon a point, yet that this power is very limited; for, that if a somewhat greater quantity be applied suddenly to a sharp point, it will not pass off silently, but create an explosion in proportion to its density. The experiments in this Essay demonstrate, that a broken communication will occasion the sharp point to receive an explosion.

Let us now consider more particularly the practical question, whether the sharp-pointed or the blunted conductors be the best preservatives from lightning. And here it is necessary to observe, that buildings may be exposed to a stroke of lightning in several different ways. The lightning, which to avoid prolixity I shall only speak of as positive electricity, the lightning, I say, may accumulate directly over the building; or it may be brought towards the building by a small cloud fetching it in several successive trips from a large cloud at some distance; or a large electrified cloud may be carried rapidly towards it by the wind, a circumstance this by no means rare, there being no less than four instances of it upon record in the Phil. Trans. vol. xlix. p. 16 and p. 309, vol. lxi. p. 72, and vol. lxiv. p. 351. In the first of these supposed cases, a sharp-pointed conductor might possibly drain the cloud of its lightning as fast as it began to accumulate, and thereby prevent any explosion whatever. In the second, as the cloud, by supposition, not being driven in one direction by the wind, could not move with any remarkable velocity, it is reasonable to imagine, that in this case also there might be no explosion, and that the electricity of the larger cloud might be gradually exhausted. But if, according to the third supposition, a cloud of great extent and highly electrified should be driven with great velocity in such a direction, so as to pass directly over the sharp-pointed conductor, there can be no doubt but that such a point from its superior readiness to admit electricity, would take the explosion at a much greater distance than a rounded end, and, in proportion to the difference of that striking distance, would do mischief instead of good.

But, perhaps it will be said, that every stroke of lightning falling upon a sharp point is previously diminished by that point, and therefore may more easily be transmitted through the conductor than when it falls undiminished upon a rounded end. Upon this supposition, I must observe, that it not only contradicts Mr. *Wilson*'s experiments at the Pantheon, but also Mr. *Henley*'s experiment already referred to in this paper, where the fire flew to a very taper point, and melted the end with a strong and loud explosion. So also the sharp-pointed conductors affixed in America to the houses of Mr. *West*, Mr. *Raven*, and Mr. *Mayne*, do not seem to have diminished the force of the explosion, if we may judge from the violence of its effects as related at large in Dr. *Franklin*'s works. It should seem, therefore, that the power of diminishing a stroke, like that of preventing it, is only contingent, and depends, as we said before, upon the degree of velocity with which the lightning moves.

The sum of the whole is, that conductors terminated by sharp points are sometimes advantageous, and at other times prejudicial. Now, as the purpose for which conductors are fixed upon buildings is, not to protect them from one particular sort of clouds only, but, if possible, from all, it cannot surely be adviseable to use that kind of conductors, which, if they diminish danger on one hand, will increase it on the other. It is the duty of a pilot to keep out of the way of rocks; but it is also incumbent upon him, in avoiding the rock, not to take so large a compass as to run his ship upon a quicksand.

When I say that sharp-pointed conductors may in some cases diminish danger, I speak of them perhaps rather too favourably; for, their power of stealing away the electric fluid being confined to cases where the accumulation is small, it follows, that they afford no protection where the danger is great and imminent, and only obviate that which is distant and problematical. The cases against which we wish principally to provide, are the explosions of extensive and highly electrified clouds; and here we have seen that blunted ends, as acting to a much smaller distance, are entitled to the preference.

If it be admitted, that sharp-pointed conductors are attended with any, the slightest degree of danger, how much must that danger be augmented by carrying them high up into the air, by fixing them upon every angle of a building, and making them project in every direction? Ought this to be advised while there is still a doubt of the possibility of their doing mischief?

OBSERVATIONS ON THE ACTION OF CONDUCTORS, &c. BY THE EDITORS OF THE ENCYCLOPÆDIA BRITANNICA.

" Ever since the discovery of the identity of electricity and lightning, it has been allowed by all parties, that conductors of some kind are in a manner necessary for the safety of buildings, in those countries where thunder storms are very frequent. The principle on which they act is this; that the electric fluid, when impelled by any power, always goes to that place where it meets with the least resistance. Now, as metals are found to give the least resistance to its passage, it will always choose to run along a metalline rod, in preference to a passage of any other kind. But it is necessary to observe here, that electricity never strikes a body merely for the sake of the body itself, but as by means of that body it can arrive at the place of its destination. When a quantity of electricity is collected from the earth, by means of an electric machine, a body communicating with the earth will receive a strong spark from the prime conductor; it receives this spark, not because it is capable of containing all the electricity of the cylinder and conductor, but because the natural situation of the fluid being disturbed by the motion of the machine, a stream of it is sent off from the earth. The natural powers, therefore, make an effort to supply what is thus drained off from the earth; and, as the individual quantity which comes out is most proper for supplying the deficiency, as not being employed for any natural purpose, there is always an effort made for returning it to the earth. No sooner then is a conducting body, communicating with the earth, presented to the prime conductor, than the whole effort of the electricity is directed against that body; not merely because it is a conductor, but because it leads to the place where the fluid is directed by the natural powers by which it is governed, and at which it would find other means to arrive, though that body were not to be presented. That this is the case, we may easily see, by presenting the same conducting substance in an insulated state to the prime conductor of the machine, when we shall find only a small spark will be produced. In like manner, when lightning strikes a tree, a house, or a thunder rod, it is not because these objects are high, or in the neighbourhood of the cloud, but because they communicate with some place below the surface of the ground, against which the impetus of the lightning is directed, and at that place the lightning would certainly arrive, though none of the above-mentioned objects had been interposed.

"When the atmosphere begins to be electrified, either negatively or positively, the earth, by means of the inequality and moisture of its surface, but especially by the vegetables which grow upon it, absorbs that electricity, and quickly becomes electrified in the same manner with the atmosphere; this absorption, however, ceases in a very short time, because it cannot be continued without setting in motion the whole of the electric matter contained in the earth itself. Alternate zones of positive and negative electricity will then begin to take place below the surface of the earth, for reasons given in the course of this Essay: between the atmosphere and one of these zones the stroke of lightning will always be. Thus, supposing the atmosphere is positively electrified, the surface of the earth will, by means of trees, &c. quickly become positively electrified also, we will suppose to the depth of ten feet; the electricity cannot penetrate further, on account of the resistance of the electric matter in the bowels of the earth. At the depth of ten feet from the surface, a zone of negatively electrified earth begins, and to this zone the electricity of the atmosphere is attracted; but to this it cannot get, without breaking through the positively electrified zone which lies uppermost, and shattering to pieces every bad conductor which lies in its way. We are therefore sure, that in whatever place the outer zone of positively electrified earth is thinnest, there the lightning will strike, whether a conductor happens to be present or not. If there is a conductor, either with a knob or sharp-pointed, the lightning will infallibly strike it: but it would also have struck a house situated on that spot without any conductor; and, if the house had not been there, it would have struck the surface of the ground itself. Again, if we suppose the house with its conductor to stand on a part of the earth where the positively electrified zone is very thick, the conductor will neither silently draw off the electricity, nor will the lightning strike it; though perhaps it may strike a much lower object, or even the surface of the ground itself at no great distance; the reason for which undoubtedly is, that there the positively electrified zone is thinner than where the conductor was.

"To suppose that a pointed conductor will exhaust a thunder cloud of its electricity, must at first sight appear trifling, to insist on it, ridiculous. Innumerable objects are all conspiring to draw off the electricity, as well as the conductor, if it could be drawn off; but of the effecting this, there is an impossibility, because they have the same kind of electricity with the clouds themselves.

"Besides, *Beccaria* has observed, that during the progress and increase of the storm, though the lightning frequently struck to the earth, yet the same cloud was the next moment ready to make a greater discharge, and his apparatus continued to be as much affected as ever.

"The conductor has not even the power of attracting the lightning a few feet out of the direction it would choose itself; of this we have a most decisive instance in what happened to the magazine at Purfleet, in Essex. That house was furnished with a conductor, raised above the highest part of the building; nevertheless, a flash of lightning struck an iron cramp in the corner of the wall of the building, considerably lower than the top of the conductor, and only forty-six feet in a sloping line distant from the point.

"The conductor, with all its power of drawing off the electric matter, was neither able to prevent the flash, nor to turn it forty-six feet out of its way. The matter of fact is, the lightning was determined to enter the earth at the place where the Board-house stands, or near it; the conductor fixed on the house offered the easiest communication, but forty-six feet of air intervening between the point of the conductor and the place of the explosion, the resistance was less through the blunt cramp iron and a few bricks moistened with the rain, to the side of the metalline conductor, than through the forty-six feet of air to its point; for the former was the way in which the lightning actually passed.

"The zig-zag kind of lightning is the most dangerous, because it must overcome a very violent resistance of the atmosphere; and, wherever that resistance is in the smallest degree lessened, there it will undoubtedly strike, and even at a considerable distance. It is otherwise with that kind that appears in flashes of no determinate form, the electric matter of which is evidently dissipated in the air by some conducting substances which are present there, and they are therefore rendered less powerful.

"The most destructive kind of lightning is that which assumes the form of balls. These are produced by an exceeding great power of electricity, gradually accumulated till the resistance of the atmosphere is no longer able to confine it. In general, the lightning breaks out from the electrified cloud by means of the approach of some conducting substance; but the fire-balls seem to be formed, not because there is any substance at hand to attract the electric matter from the cloud, but because the electricity is accumulated in such a quantity, that the cloud can no longer contain it. Hence, such balls fly off slowly, and have no particular destination; their appearance indicates a prodigious commotion and accumulation of electricity in the atmosphere, without a proportionable disposition in the earth to receive it. This disposition is, however, altered by a thousand circumstances, and the place which first becomes most capable of admitting electricity will first receive a fire-ball. Hence, this kind of lightning has been known to move slowly backwards and forwards in the air for a considerable time, and then suddenly fall on one or more houses, according to their being more or less affected with an electricity opposite to that of the ball at the time. It will also run along the ground, break into several parts, and produce several explosions at the same time.

"It is very difficult to imitate this kind of lightning in our electrical experiments. The only cases in which it hath been done in any degree, are those in which Dr. *Priestley* made the explosion of a battery pass for a considerable way over the surface of raw flesh, water, &c. In these cases, if, while the electric flash passed over the surface of the flesh, it had been possible to interrupt the metallic circuit by taking away the chain, the electric matter discharged would have been precisely in the situation of one of the above-mentioned fire-balls; *i. e.* it would have been at a loss for a conductor. The negative side of the battery was its place of destination, but to that it could not easily have got, because of the great quantity of atmosphere which lay in its way, and the incapacity of the neighbouring bodies to receive it. But, while the electric matter was thus stationary for want of a conductor, if any one standing near, or touching the negative side of the battery, presented a finger to this seemingly inoffensive luminous body, he would be instantly struck very violently, because a free communication being now made by means of his body, the powers by which the electric fluid is impelled from one place to another would urge it upon him. But if we suppose a person, who has no communication with the battery, to present his finger to the same body, he may perhaps receive a slight spark from it, but not a shock of any consequence.

"We may now account for the seemingly capricious nature of all kinds of lightning, but especially of that kind which appears in the form of balls. Sometimes it will strike trees, high houses, &c. without touching cottages, men, or animals, who are in the neighbourhood; in other instances, low houses and cattle have been struck, while high trees and steeples in the neighbourhood have escaped.* The reason of this is, that in thunder storms there is a zone of earth consi-

* Of this, two remarkable instances have been adduced, in a paper read by Mr. *Achard* at the Berlin Academy of Sciences. And *Beccaria* cautions persons from depending on a higher, or, in all cases, a better conductor than their own body.

derably under the surface which the lightning desires to strike, if we may use the expression, because it has an electricity opposite to the lightning itself. Those objects, therefore, which form the most perfect conductors between the electrified clouds and that zone of earth, will be struck by lightning, whether they are high or low. Let us suppose a positively electrified cloud is formed over a certain part of the earth's surface; the electric matter flows out from it first into the atmosphere all around, and while it is doing so, the atmosphere is electrified negatively. In proportion, however, as the current pervades greater and greater portions of the atmospherical space, the resistance to its motion increases, till at last the air becomes positively electrified as well as the cloud, and they both act as one body. The surface of the earth then begins to be electrified, and it silently receives the electric matter by means of the trees, grass, &c. which grow upon its surface; till at last it becomes also positively electrified, and begins to send off a current of electricity from the surface downwards.

"The causes which first produced the electricity still continuing to act, the power of the electric current becomes inconceivably great. The danger of the thunder storm now begins; for, as the force of the lightning is directed to some place below the surface of the earth, it will certainly dart towards that place, and shatter every thing to pieces which resists its passage.

"The benefit of conducting rods will now also be evident. For, we are sure the electric matter will, in all cases, prefer that way where it meets with the least resistance, and this is over the surface of metals. In such a case, therefore, if there happen to be a house furnished with a conductor directly below the cloud, and at the same time a zone of negatively electrified earth not very far below the foundation of the house, the conductor will almost certainly be struck, but the building will be safe. If the house wants a conductor, the lightning will nevertheless strike in the same place, in order to get at the electrified zone abovementioned; but the building will be now damaged, because the materials of it cannot readily conduct the electric fluid."*

* See Encyclopædia Britannica, Art. Lightning, vol. vi. p. 4224.

That the electric matter, which forms and animates the thunder-clouds, issues from places far below the surface of the earth, and buries itself there, is probable from the deep holes that have been made in many places by lightning, by the violent inundations that have accompanied thunder storms, not occasioned by rain, but by water bursting from the bowels of the earth, from which it must have been dislodged by some internal concussion, &c. See Dr. *Priestley*'s History of Electricity, p. 328.

CHAP. XV.

TO CHARGE A PLATE OF AIR.

As air is an electric, it will receive a charge like all other electric substances. To this property may be ascribed many of the phenomena which are observed in the course of the common electrical experiments; for, the air which surrounds an electrified non-electric is always in some degree charged with the fluid, and thus acts upon the atmosphere of the electrified conductor, not only by its pressure, but also by its acquired electric powers; and that it pervades the air to a considerable distance, is evident from the different methods by which the air of a room may be electrified.

Cover two large boards with tin-foil; suspend one by silken strings from the ceiling, and then connect it with the conductor; place the other board parallel to the former, on an insulating stand that may be easily raised or lowered, to regulate the distance of the plates from each other. Or, place the boards in a vertical situation, on insulating stands of the same height. In most cases this form will be found the most convenient.

These boards may be considered as the coatings to the plate of air which is between them.

EXPERIMENT CCIX. Connect the upper board with the positive conductor, and the other with the ground; turn the cylinder, and the upper one will be electrified positively, and the under one negatively; the space of air between the two plates acts as a plate of glass, it separates and keeps asunder the two electric powers. Touch the negative plate with one hand, and the upper one with the other, and a shock will be received similar to that from the Leyden jar.

The electric shock will always be felt whenever a quantity of the fluid passes through any body in an instantaneous manner, and the force of the shock will be proportional to the quantity of electricity accumulated, and the ease with which it can escape; for, the whole energy of the electricity depends on its tension, or the force with which it endeavours to fly off from the electrified body.

The two plates, when in contrary states, strongly attract each other, and will come together, if they are not kept asunder by force. A spark will sometimes pass between the plates, and destroy the electricity of each. If an eminence is placed on the under plate, the spark, in the spontaneous discharge, will strike it. The experiments with these boards will be more pleasing, if one surface of the upper board is covered with gilt leather. The two plates, when charged, are supposed to represent the state of the earth and the clouds in a thunder-storm; the clouds being in one state, and the earth in an opposite one, while the plate of air acts as the electric, and the spontaneous discharges exhibit the phenomena of lightning.

An observation has been made on this experiment, which seems to affect one of the principal supports of the received theory. I have subjoined it, in order to invite those who are conversant with electricity to a closer investigation of the subject.

In this experiment, it seems impossible to deny that air is penetrated by the electric fluid. The distance between the plates is so small, that it must appear absurd to say, that this space is penetrated only by a repulsive power, when in other cases we see the fluid pervading much greater spaces of air. But, if one electric substance is penetrable by the electric fluid, we must be led strongly to suspect at least that all the rest are so too. If glass was altogether impenetrable to the fluid, it is natural to think that it would run over its surface very easily; but, instead of this, so great is its propensity to enter, that a shock sent through between two glass plates, if they are pressed pretty close together, always breaks them to pieces, and even reduces part of them to a powder like sand. This last effect cannot be attributed to any other, than the electric fluid entering the pores of the glass, and, meeting with resistance, the impetus of its progressive motion violently forces the vitreous particles asunder in all directions.

Experiment ccx. Turn that side of the upper board, on which the gilt leather is pasted, towards the lower one; place one or two small metal hemispheres on the lower board; connect the upper board with the positive conductor, and the lower one with that which is negative, put the machine in action, and the upper board will discharge the whole of its contents on one of the hemispheres in a strong flash, attended with a smart explosion; vivid corruscations of electric light will be seen darting in various directions on the surface of the gilt leather. This experiment, says Mr. *Becket*, is more than a resemblance of lightning, it is nature invested in her own attire.

Connect a coated jar with the positive conductor, so that it may be discharged with the boards, and the flashes of light will extend farther, and the explosion will be louder.

Experiment ccxi. Place the wire, *fig.* 10, with the feathers tied to it, in the middle of one of these large boards; their divergence will not be near so much in this situation, as when they are at the edge of the board. If a piece of down or a feather is placed near the edge of the board, it will fly off to the nearest non-electrified body; but, if it is placed in the middle, it will be a considerable time before it will move, and it will scarcely shew any signs of attraction.

Experiment ccxii. Place bran, or small pieces of paper, near the center of the lower board; when the machine is put in action, these will be alternately attracted and repelled with great rapidity, and agitated in an amazing manner. A pleasing variation is made in this experiment by taking off the chain from the lower board, and now and then touching it with the hand; touch both boards at the same time, and the motion ceases. But, the most surprizing appearance in this experiment is, that sometimes when the electricity is strong, a quantity of paper or bran will accumulate in one place, and form a kind of column between the boards; it will suddenly acquire a swift horizontal motion, moving like a whirling pillar to the edge of the boards, and from thence fly off, and be scattered about the room to a considerable distance.

Experiment ccxiii. Take two jars, the one charged positively, the other negatively; place them on the insulated board, but as far from each other as the board will permit; insert a range of candles in a piece of wood, about two inches distance from each other, so that the flame of each may be exactly parallel: when these candles are quickly introduced between the knobs of the jars, the spark will be seen to dart through all of them, and will have the appearance of a line of fire, variegated in a thousand different curves.

CHAP. XVI.

OF THE ELECTROPHORUS, AND MR. BENNET'S EXPERIMENTS THEREWITH.

Fig. 73, represents an electrophorus. This instrument was invented by Mr. *Volta*, of Coma in Italy.* It consists of two plates of a circular form; the under plate is of brass covered over with a stratum of an electrical substance, generally of some negative electric, as wax, sulphur, &c. the upper plate is of brass, with a glass handle screwed on the center of its upper surface.

Resinous electrics generally succeed better for an electrophorus than those made only of glass, not only as they are less affected by the humidity of the air, but as they seem to have the power of retaining longer the electricity which is communicated to them.

To use this apparatus, first excite the under plate, by rubbing its coated side with a piece of clean dry flannel, or hare-skin; when this plate is well excited, it is to be laid on the table with the electric uppermost. Secondly, place the metal

* Mr. *Wilck*, in August 1762, contrived a resinous apparatus, to which he gave the name of a Perpetual Electrophorus. See *Scripta Academiæ Suec.* 1762.

plate upon the electric as in *fig.* 74 and 75. Thirdly, touch the metal plate with the finger, or any other conductor. Fourthly, separate the metal plate from the electric by the glass handle. This plate, when raised to some distance from the under one, will be found strongly electrified with the power which is contrary to that of the electric plate, and will give a spark to any conductor that is brought near it. By repeating this operation, *i. e.* by setting the metal plate on the electric, and then touching it with the finger, a great number of sparks may be successively obtained without a fresh excitation of the electric.

Experiment ccxiv. By examining the electrophorus with small pith balls, we find,

1. That as soon as the upper plate is placed on an electrophorus of wax, it acquires a weak positive electricity; and the contrary, if placed on an electrophorus of glass.

2. That when the upper plate is touched by the finger, it loses all its electricity.

3. When the upper plate is touched by the finger, and removed from the electrophorus, it acquires a strong negative electricity, if the electrophorus is of glass; and a positive electricity, if it is of wax.

The electrophorus may be considered as formed of several horizontal strata; so that when the upper one is excited, either by friction or communication, it is insulated by the inferior strata. Now all insulated electrics preserve their electricity a considerable time, and it is from that cause that the electricity of the electrophorus continues so long.

Insulated and excited glass induces the negative electricity on bodies brought within the sphere of its action, while negative electrics, in similar circumstances, produce the positive electricity. Therefore, the surface of the electrophorus ought to communicate immediately a positive electricity, if it is of wax; the negative, if it is made of glass: which is perfectly conformable to experiments. But when the upper plate is touched by the finger, the upper surface of the electrophorus ceases to be insulated, and gives the negative electricity to the upper plate, if it is of glass; and the contrary, if of wax; agreeable to the different experiments which are described in this Essay.

Electric bodies do not put the fluid in that degree of motion, which is necessary to produce the spark, or exhibit the phenomena of attraction and repulsion, while they are in contact with conducting substances; which is the reason why the upper plate exhibits no signs of electricity while it remains in contact with the under one, though they become sensible the instant it is removed from it.

"In the case of a glass electrophorus, as it is a case which admits of a somewhat easier illustration, the excited plate acts upon the electric matter naturally contained in the upper brass plate, so as to repel a part of its natural quantity from it in form of a spark, at that part where the finger is applied to it. If the brass plate in this state is lifted up by its handle, it will receive a spark from the finger. On being replaced, and the same operation taking place, the same result will be obtained; which may be continued for a great length of time, without diminishing the virtue of the excited electric, which in fact does not part with any of its own electricity, but only repels a part of what is in the upper plate, which is repeatedly restored to it from the earth by the person who makes the experiment."

Experiment ccxv. Place a piece of metal on an excited electrophorus, it may be of any shape; a pair of triangular compasses are very convenient for this purpose. Electrify the piece of metal with the power which is contrary to that of the electrophorus, and then remove it by means of some electric, and afterwards sift upon the electrophorus some finely powdered resin, which will form on its surface curious radiated figures. When the plate is negative, and the piece of metal positive, the powder forms itself principally about those parts where the metal was placed; but, if the plate is positive, and the spark is negative, the part where the metal touched will be free from powder, and the other parts more covered.

EXPERIMENT CCXVI. *To recover the force of an electrophorus by itself.* Place the metallic cover on the resinous cake, touch it as usual; then take it up, and discharge it on the knob of a Leyden jar; repeat this operation several times, and then place the jar on the cake, and move it over its surface, holding the jar by the knob; this will augment the force of the electrophorus, and by reiterating the operation it will become very powerful.

EXPERIMENT CCXVII. Insulate a metal quart mug, and suspend a pair of small pith balls by silk, so that the whole of the electrometer may be within the mug; electrify the mug, and the electrometer will not be in the least affected. The similar atmospheres counteract each other; and, as no contrary power can take place in the electrometer, it will remain unelectrified. Touch the mug with some conducting substance, and it will immediately attract the balls.

EXPERIMENT CCXVIII. Suspend a small cylinder of gilt paper by tin-foil, and then touch the electrified and insulated mug with it; a spark will pass between them, and the electricity will be diffused in each in proportion to their capacity. Now plunge the insulated cylinder to the bottom of the mug, and it will restore to it the electricity it had received, but does not give the least sign of electricity when taken out.

EXPERIMENT CCXIX. Connect a pair of pith balls with an insulated metal vessel, in which a metal chain is placed; raise the chain by means of a silk thread, and the divergence of the balls will diminish in proportion as the chain is raised and displayed; shewing, that the electricity is rarefied, and its density is diminished, in proportion as it spreads itself from the surface of the vessel on the extended chain; which is confirmed by the balls diverging again when the chain is let down into the vessel. This experiment affords an easy solution for many of the phenomena of atmospheric electricity; as, why the vapour of electrified water gives such small signs of electricity, and why the electricity of a cloud is increased by being compressed or condensed.

EXPERIMENT CCXX. Excite a slip of white flannel, or a silk ribbon, and take as many sparks from it as it will give; then double or roll it up, and the contracted flannel will be strongly electrical, give sparks, and throw out brushes of light.

NEW EXPERIMENTS WITH MR. LICHTENBURG'S LARGE ELECTROPHORUS, BY THE REV. MR. BENNET; AND EXTRACTED FROM HIS WORK, ENTITLED, "NEW EXPERIMENTS ON ELECTRICITY."

The following experiments are intended as improvements on Mr. *Lichtenburg*'s beautiful configuration; first made on a resinous electrophorus, by drawing over it the knob of a charged jar, and then rendered visible by sifting powdered resin over the plate; which falling very differently, according to the circumstances in which the experiment is made, exhibits the diffusion of electricity in a very pleasing manner; see *plate* 5, *fig.* 101, 102.

Mr. *Bennet*'s first electrophorus was a glass plate fifteen inches square, covered on one side with a thin resinous black coating, with tin-foil pasted on the other side; for, if the side opposite to the resinous one be not a conductor, the electrical fluid will not be easily diffused over it. Glass was used that the electricity might not be so liable to pass through the small holes and blistered places, which cannot well be avoided if the resinous substance be thinly spread upon wood or metal.

As powdered resin projected from a brush is negatively electrified, there appeared no doubt but that chalk and other powders, which by the same means are negatively electrified, would answer as well, or better; such powders were therefore tried, and found to succeed remarkably well.

EXPERIMENT CCXXI. The plate was suspended by a loop against a wall, that the grosser part of the powder might fall to the ground, and no more adhere to the plate than was attracted by the electricity diffused thereon. A small jar was charged very weakly by one revolution of the electrical machine, and after its knob had been drawn over the resinous plate, a cloud of chalk was projected by rubbing the lump upon a brush near the electrified surface of the plate; this produced a plain white line without any ramifications.

EXPERIMENT CCXXII. When the jar was charged by three revolutions of the machine, ramifications appeared upon the plate at a considerable distance from each other.

EXPERIMENT CCXXIII. Five or six revolutions caused the electrical fluid to spread upon the plate in ramifications very near each other. Close to each branch a small space was left uncovered with powder, forming a kind of shade to the figure. Beyond this shade the powder lay smooth, softening off externally.

EXPERIMENT CCXXIV. With a very strong charge the ramifications were close and broad, resembling white feathers with a very broad shade.

EXPERIMENT CCXXV. A circular brass plate with an insulating handle was placed upon the resinous plate, and a spark from the charged jar was communicated to the brass plate, which was then taken off by its insulating handle, and chalk projected, which produced a very regular circle of ramifications about four inches long, proceeding from the circumference of the space covered by the brass plate, and within the circle were a number of irregular figures somewhat like stars. A shock made to pass through the same plate generally produced more distinct ramifications, and sometimes without any stars within the circle; and if the brass plate was drawn along towards the edge of the electrophorus whilst touched with the knob of the jar, a very beautiful figure, see *plate* 5, *fig.* 101, was produced.

EXPERIMENT CCXXVI. A jar strongly and negatively charged was drawn over the plate, and afterwards a pointed wire, held in the hand only, was drawn over the same figure; then chalk was projected, which produced a beautiful ramified figure in the middle of the negative one.

EXPERIMENT CCXXVII. A conical tin funnel was placed with its base on the middle of the resinous plate, and a negative strong charge given by connecting the discharging rod with the under side of the plate; then a positive charge was given in the same manner: the funnel was thrown off and chalk projected, which produced very beautiful ramifications both within and on the outside of the circle.

EXPERIMENT CCXXVIII. A knob of wood, about an inch in diameter was placed upon the wire of a jar which was charged highly positive, and the knob drawn over the plate so as to touch the surface; this produced a beautiful figure, the middle of which was smoothly covered with chalk, and the sides finely ramified with shades.

EXPERIMENT CCXXIX. A small candle was insulated, and its flame placed about an inch distant from the middle of the resinous plate; then the knob of a positively charged jar was suddenly brought to the flame, and both the flame and jar instantly taken away again. In this experiment, when the chalk was projected, a circular space about four inches in diameter was clean and free from powder; the rest of the plate was covered, except a great number of small circular or elliptical spots, which shews that the electrical fluid passed to the plate in detached balls, like some atmospheric meteors; or the plate absorbed from the air a contrary state of electricity, which produced this appearance.

Experiment ccxxx. If a positive figure be first drawn, and then a negative one across it, or *vice versa*, when the powder is projected, it is easy to distinguish which was first drawn, the second appearing to cover the first; and, when the positive figure is made last, the ramifications at the place of junction extend farther than the rest, and are left without powder; but, if both the strokes are positive or negative, the first will appear to cover the second.

Experiment ccxxxi. If powders of different colours are mixed, and projected over the figures, some of the colours will prevail on the middle and some on the outside, and especially if two figures whose electricity is contrary are made on the same plate; and most of all, when both the electrical states of the figures and powders are contrary: for example, if minium, whose electricity is strongly positive, and sulphur, very strongly negative, be powdered together, and then this mixed powder be put into the bellows, and blown upon the contrarily electrified figures, the powders separate, and the sulphur falls upon the positive figure, and the minium on the negative: this produces a very pleasing effect.

CHAP. XVII.

OF MR. VOLTA'S CONDENSING PLATES; OR, OF THE ADVANTAGES WHICH MAY BE DERIVED FROM AN IMPERFECT INSULATION; AND OF RENDERING VERY SENSIBLE VERY SMALL DEGREES OF NATURAL AND ARTIFICIAL ELECTRICITY.*

A Conductor, properly constructed for making observations on atmospherical electricity, seldom affects the most sensible electrometer when the sky is free from electrical clouds; but, by means of the apparatus now to be described, it will appear, that these conductors are always electrical, and consequently the air that surrounds them must be at all times electrified. This method not only determines the existence, but also the quality of the electricity, whether positive or negative, and that, even when the conductor will not attract the finest thread; but, if a very small attraction is visible in the conductor, then the apparatus will give long sparks.

The electrophorus used for this purpose, may with propriety be termed a micro-electrometer, or condenser of electricity.

* Phil. Trans.

Whenever the atmospherical conductor gives sufficient signs of electricity, then the condensing apparatus becomes useless. For, when the electricity is strong, it often happens that part of the electricity of the metal plate is impressed upon the other, in which case the apparatus acts as an electrophorus, and becomes unfit for our purpose.

The apparatus adapted for this purpose consists of the upper plate of an electrophorus, and a semi-electric, or an imperfect conducting plane, which will only hinder in a certain degree the passage of the fluid. Many conductors of this kind may be formed; such as a clean dry marble slab, a plate of wood covered with a coat of varnish, &c. the surface of those bodies not contracting electricity, or if any should adhere to them, it soon vanishes on account of their semi-conducting nature; for which reason they cannot answer the end of an electrophorus, but are fit to be used as condensers of electricity.

Care should be taken however in choosing this plane, that it be not of too free a conducting nature, nor likely to become so by use, it being absolutely necessary that the electricity should find a considerable resistance in pervading its surface. In preparing such a plane, by drying or otherwise, it is much better to come too near than too far from a non-conductor. A marble slab, or board properly dried, answers well, and is preferablè to any other plane; otherwise the plate of the electrophorus is preferable to all bodies unprepared.

The worst sort of marble, if coated with copal, amber, or lac-varnish, and then kept in an oven for a short time, will answer very well, even without previously warming for the experiment.

This in fact, it may be said, is returning to the electrophorus; as marble, wood, &c. varnished, if they are hot, may be excited by a very slight friction, and sometimes by only laying the metal plate on them; to prevent which, they should be used without warming.

The advantages plates of this kind have over the common electrophorus are, 1. That the varnish is always thinner than the common resinous stratum of an electrophorus; and 2. That the varnish acquires a smoother and plainer surface: hence the metal plate can with more advantage be adapted to it.

Any sort of plane, covered with dry and clean oil-cloth, or oiled silk or satin, and any other silk stuff that is not very thick, may be used with equal advantage, if it is slightly warmed. Silk stuffs answer better for this purpose than those made of cotton or wool, and both better than linen. Paper, leather, wood, ivory, bone, and every other sort of imperfect conductors, may be made to answer to a certain degree, if they are previously dried, and kept hot during the experiment.

This apparatus is rendered more simple by applying the silk, &c. to the upper plate of metal, which is fixed to the glass handle, instead of the marble or other plate, which now becomes useless; for in its stead, a plane of any kind may be used, as a common wooden or marble table, even not very dry; a piece of metal, a book, or any other conductor with a flat surface.

Nothing more is requisite in these experiments, than that the electricity, which tends to pass from one surface to the other, should meet with some resistance or opposition in one of the surfaces.

It is immaterial, whether the non-conducting or semi-conducting stratum be laid upon one or the other of those planes; all that is necessary is, that they should coincide together, which renders it proper to use two planes that have been ground together, and one of them varnished. A single metal plate covered with silk, with three silk strings fastened to it by way of handle, may be conveniently used for ordinary experiments.

To use the apparatus, the upper metal plate must be placed upon the unelectrified plate and in perfect contact with it.

The plates being thus placed, let a wire communicating with the conductor be brought to touch the metal plate of the electrophorus, and that only.

The apparatus being left in that situation a certain time, will acquire a sufficient quantity of electricity, but very slowly.

Remove the communicating wire from the metal plate, and by means of its insulated handle separate it from the under one; it will now attract a thread, electrify an electrometer, and, if it is strong, will give sparks, &c. though the atmospherical conductor shewed no, or only small signs of it.

It is not easy to determine the exact time necessary for this apparatus to remain in contact with the conductor, as it will depend on many circumstances; for, if there are no signs of electricity in the conductor, it will require eight or ten minutes, but if it attracts fine thread, as many seconds will be found sufficient.

It is difficult also to determine the precise degree to which the electricity may be condensed, or how much the electrical phenomena may be increased by this apparatus, as it depends on various circumstances. The augmentation is, however, greater in proportion as the body which supplies the metal plate has a greater capacity, and is larger in proportion as the electricity is weaker. Thus, though the atmospherical conductor has scarcely power sufficient to attract a fine thread, it is nevertheless capable of giving such a quantity of electricity to the metal plate of the electrophorus, as not only to actuate an electrometer, but even dart strong sparks. But if the electricity of the atmospherical conductor is strong enough to afford sparks, or to raise the index of the electrometer to five or six degrees, then the receiving plate of the electrophorus, according to this method, will raise its index to the highest degree and give a stronger spark; yet it may be plainly perceived, that the condensation is proportionably less in this than in the other case; for this reason the electricity cannot be accumulated beyond the greatest degree; that is to say, when it is increased so much as to be dissipated every way: therefore, as the electric power which supplies the condenser is nearest to the highest degree, the condensation is proportionably less; but in this case the condenser is useless, its principal use being to collect and render sensible that small quantity of electricity, which would otherwise remain imperceptible aed unobserved.

Hitherto we have adapted our condenser to the detecting weak atmospherical electricity, as brought down by the conductor; but this, though the principal, it not the only use to which it may be applied. It will likewise discover artificial electricity, when it is so weak as not to be discoverable by any other means.

A Leyden jar charged, and then discharged by touching its coated sides with the discharging rod or the hand, appears to be quite deprived of its electricity; yet, if you touch the knob of it with the metal plate of the condenser, situated upon an imperfect conducting plane, and immediately take up the plate, it will be found to give very conspicuous signs of electricity. But, if just sufficient charge is left in the jar to attract a fine thread, and the metal plate is then brought to touch the knob for a moment, it will, when lifted up, give a strong spark, and if touched again, a second scarce smaller than the former; and thus spark after spark may be obtained for a long time.

This method of producing sparks, by means of a jar which is not charged so high as to give sparks of itself, is very convenient for various pleasing experiments; as to fire or light the inflammable-air pistol or lamp; especially when a person is provided with one of those jars contrived by Mr. *Cavallo*, which, when charged, may be carried in the pocket a long time. These jars, as they retain a sensible charge for several days, will retain an insensible one for weeks and months; or, such a one as cannot easily be discovered without the condenser, in which case it becomes more than sensible, and sufficient for the experiments of the imflammable-air pistol, &c.

Secondly. If you have an electrical machine so far out of order, that its conductor will not give a spark nor attract a thread, then let this conductor touch the metal plate of the condenser, and continue in that situation a few minutes; the machine being still in motion, lift up the metal plate, and you will obtain from it a strong spark.

Thirdly. If the electrical machine acts well, but the conductor is so badly insulated that it will not give a spark, either from its being connected with the walls of the room, or by having a chain from it to the table, let the conductor in this state touch the metal plate of the condenser, while the machine is in action, the plate will afterwards give sufficient strong signs of electricity; which proves the great power this apparatus has of drawing and condensing the electricity.

Fourthly. Where the electrometers are not sufficiently sensible to discover the quantities of excited electricity, those quantities may be readily explored by the condenser. For this purpose, rub those bodies with the metal plate of the condenser, which for this purpose must be naked, and if the plate be then presented to an electrometer, it will be found considerably electrified, although the body rubbed may have acquired little or no electricity. The quality, whether positive or negative, may easily be ascertained, since the electricity of the metal plate must be the contrary of that body on which it was rubbed. Mr. *Cavallo* made use of this method to discover the electricity of many bodies. But still a better method may be used, in case the bodies to be examined cannot easily be adapted to the metal plate, *viz.* the metal plate being laid on the imperfect conducting plane, the body to be tried is rubbed against, or repeatedly stroked upon it, which done, the plate is taken up and examined by an electrometer. If the body tried is leather, a string, cloth, velvet, or other imperfect conductor of the like sort, the plate will certainly be found electrified, and incomparably more by this means, than if it were stroked by the same bodies, whilst standing insulated in the air. In short, by either of those methods you will obtain electricity from bodies which could hardly be expected to give any, even when they are not very dry. Indeed, coals and metals excepted, every other body will afford some electricity. Electricity may often be obtained by stroking the plate with the naked hand.

The metal plate has a much greater power to retain electricity when it lies upon a proper plane, as mentioned in the foregoing experiments, than when quite insulated.

It is easy to comprehend, that where the capacity of holding electricity is greatest, there the intensity of the electricity is proportionably less, for it will then require a greater quantity to raise it to a given degree of intensity; so that the capacity is inversely as the intensity; by which we mean, that endeavour, by which the electricity of an electrified body tends to escape from all parts of it; to which tendency, or endeavour, the electrical phenomena of attraction and repulsion, and especially the degree of elevation of an electrometer, correspond.

That the intensity of electricity must be inversely proportioned to the capacity of the body electrified, will be clearly exemplified by the following experiment.

EXPERIMENT CCXXXII. Take two metal rods of equal diameters, the one a foot, the other five feet long; let the first be electrified till the index of the electrometer rises to 60°, then let it touch the other rod; and in that case it is evident, that the intensity of the electricity, being diffused between the two rods, will be diminished as the capacity is increased; so that the index of the electrometer, which before was elevated to 60°, will now fall to 10°, *viz.* to one-sixth of the former intensity. For the same reason, if the like quantity of electricity was communicated to a rod 60 feet long, its intensity would be diminished to one degree; and, on the contrary, if the electricity of the long conductor was contracted into the 60th part of that capacity, its intensity would be increased to 60°.

Conductors of different bulks have not only different capacities for holding electricity, but also the capacity of the same conductor is increased and diminished in proportion as its surface is enlarged and contracted; as is shewn in Dr. *Franklin's* experiment of the can and chain, &c. from which it has been concluded, that the capacity of conductors is in proportion to their surface, and not to their quantity of matter.

This conclusion is true, but does nor comprehend the whole theory, since even the extension contributes to increase the capacity. In short, it appears from all the experiments hitherto made, that the capacity of conductors is not in proportion to the surfaces in general, but to the surfaces which are free or uninfluenced by similar or homologous atmospheres; and further, that the capacity of a conductor, neither altered in its form or surface, is increased when, instead of remaining quite insulated, it is presented to another not insulated; and this increase is more conspicuous, as the surfaces of the conductors are larger, and approach nearer to each other.

The above-mentioned circumstances, by which the natural capacity of conductors is greatly augmented, has been overlooked, and therefore no advantage has hitherto been deduced from it. The following experiment will shew this increased capacity in the simplest manner.

EXPERIMENT CCXXXIII. Take the metal plate of an electrophorus, hold it by its handle in the air, and electrify it so that the index of an electrometer annexed to it may be elevated to 60°, then lower the plate by degrees to a table or other plain conducting surface, the index will gradually fall from 60°, to 50°, 40°, 30°, &c. and yet the quantity of electricity in the plate remains the same, except it is brought so near the table, as to occasion a transmission of the electricity from the former to the latter; at least, it will remain as near the same, as the dampness of the air, &c. will permit. The decrease of intensity is owing to the increased capacity of the plate, which is now not insulated, or *solitary*, but *conjugate* or communicating with another conductor: for, let the plate be gradually removed from the table, the electrometer will rise again to its former station, namely to 60°; excepting the loss that the air, &c. may have occasioned during the experiment.

The reason of this phenomenon is easily derived from the action of electric atmospheres. The atmosphere of the metal plate, which for the present I shall suppose electrified positively, acts upon the table or other conductor to which it is presented; so that the electric fluid in the table retiring to the remoter parts of it, becomes more rare in those parts which are exposed to the metal plate, and this rarefaction increases the nearer the electrified metal is brought to the table: if the metal plate is electrified negatively, the contrary effects take place. In short, the parts which are immersed in the sphere of action of the electrified plate, by contracting a contrary electricity, give the electricity of the metal plate an opportunity to expand itself, and will thus diminish its intensity, as is shewn by the depression of the electrometer.

The two following experiments will throw more light upon the reciprocal action of the electric atmospheres.

Experiment ccxxxiv. Electrify two flat conductors, either both positively or negatively; then bring them gradually towards each other, and it will appear, by two annexed electrometers, that the nearer they approach each other, the more their densities will increase, as all elastic bodies re-act in proportion as they are acted on; which shews, that either of the two conjugate powers has a much less capacity to receive more fluid now, than when singly insulated, and out of the influence of the other.

This experiment explains, why the tension of the electric atmosphere on an electrified conductor is greater when it is contracted into a smaller bulk; and also, why a long extended conductor will shew less intensity than a more compact one, supposing their quantity of surface and electricity to be the same; because the homologous atmospheres of their parts interfere less with each other in the former than in the latter case, and of course, as their action is less, the re-action is also less.

Experiment ccxxxv. Electrify one of these flat conductors positively, the other negatively, and the effects will then be just the reverse of the preceding, *viz.* the intensity of their electricities will be diminished, because their capacities, or their power and facility of expanding, are increased, the nearer the conductors come to each other.

Apply the explanation of this last experiment to that mentioned before, *viz.* the bringing the electrified metal plate towards a conducting plane which is not insulated; for, as this plane acquires a contrary electricity, it follows, that the intensity of electricity in the metal plate must be diminished, and the annexed electrometer is depressed according as the capacity of the plate is increased, or as the density of its atmosphere is diminished; and, consequently, the plate in that situation is capable of receiving a greater quantity of electricity.

This will be rendered still clearer by the following experiment.

EXPERIMENT CCXXXVI. Insulate the conducting plane whilst the other electrified plate is upon it, and afterwards separating them, both the metal plate and conducting plane, which may be called the inferior plane, will be found electrified, but possessed of contrary electricities, as may be ascertained by electrometers.

If the inferior plane is insulated first, and then the electrified plate is brought over it, the latter will cause an endeavour in the former to acquire a contrary electricity, which the insulation prevents from taking place; hence the intensity of the electricity of the plate is not diminished, at least, the electrometer will shew a very little and almost imperceptible depression; which small depression is owing to the imperfection of the insulation of the inferior plane, and to the small rarefaction and condensation of the electric fluid, which may take place in different parts of the said inferior plane. But if, in this situation, the inferior plane be touched so as to cut off the insulation for a moment, then it will acquire the contrary electricity, and the intensity in the metal plate will be diminished.

If the inferior plate, instead of being insulated, were itself a non-conducting substance, then the same phenomena would happen, *viz.* the intensity of the electrified metal plate laid upon it would not be diminished. This, however, is not always the case, for if the said inferior non-conducting plane is very thin, and is laid upon a conductor, then the intensity of the electrified metal plate will be diminished, and its capacity will be increased by being laid upon the thin insulating stratum; as in that case, the conducting substance which stands under the non-conducting stratum, acquiring an electricity contrary to that of the metal plate, will diminish its intensity, &c. and then the insulating stratum will only diminish the mutual action of the two atmospheres more or less, according as it keeps them at greater or smaller distances from each other.

The intensity or electric action of the metal plate, which diminishes gradually as it is brought nearer and nearer to a conducting plane not insulated, becomes almost nothing when the plate is nearly in contact with the plane, the compensation or natural balance being nearly perfect. Hence, if the inferior plane only opposes a small resistance to the passage of the electricity, whether such resistance is occasioned by a thin electric stratum, or by the plane's imperfect conducting nature, as is the case with dry wood, marble, &c. that resistance joined to the interval, however small, that is between the two plates, cannot be overcome by the weak intensity of the electricity of the metal plate, which on that account will not dart any spark to the inferior plane, except its electricity were very powerful, or its edges not well rounded, and will rather retain its electricity; so that, being removed from the inferior plane, its electrometer will nearly recover its former height. Besides, the electrified plate may even come to touch the imperfectly conducting plane, and may remain in that situation for some time; in which case, the intensity being reduced almost to nothing, the electricity will accordingly pass but slowly to the inferior plane. But the case is different, if, in performing this experiment, the electrified metal plate touches the inferior plane edgewise, for then its intensity being greater than when it is laid flat, as appears by the electrometer, the electricity easily overcomes the small resistances and passes to the inferior plane, even across a thin stratum, because the electricity of one plane is balanced by that of the other, only in proportion to the quantity of surface which they oppose to each other within a given distance; so that when the metal plate touches the other plane in flat and ample contact, its electricity is not dissipated. This apparent paradox is clearly explained by the theory of electric atmospheres.

It is still more like a paradox, that neither touching the metal plate with a finger or piece of metal will deprive it of all its electricity, while standing upon the proper plane; so that it generally leaves it so far electrified, that when separated from the plane, it will give a spark. Indeed this phenomenon could not be explained on the supposition, that the finger or metal were perfect conductors. But, since we do not know of any perfect conductor, the metal or finger oppose a sufficient resistance to retard the immediate dissipation of the electricity of the plate, which is in that case actuated by a very small degree of intensity or power of expansion; so that suppose, for instance, the piece of metal or finger touching the plate took off so much of its electricity, as to reduce the intensity of the remainder to the 50th part of a degree, this remaining electricity would be then nothing; but when the plate, by being separated from the inferior plane, has its capacity so far diminished, as to render the intensity of its electricity 100 times greater, then the intensity of that remaining electricity would become of two degrees, or more, *viz.* sufficient to afford a spark.

Having considered in what manner the action of electric atmospheres modifies the electricity of the metal plate in its various situations, we shall now consider the effects which take place, when the electricity is communicated to the metal plate, whilst standing upon a metal plane. As the whole business has been proved in the preceding pages, it is easy to deduce the applications from it: nevertheless, it will be useful to exemplify it by an experiment.

Experiment ccxxxvii. Suppose a Leyden jar, or a conductor, so weakly electrified that its intensity is one-half a degree, or even less; if the metal plate of the condenser, when standing upon its proper plane, was to be touched with that jar or conductor, it is evident that either of them would impart to it a quantity of its electricity proportional to the plate's capacity, *viz.* so much as should make the intensity of the electricity of the plate equal to that of the electricity in the conductor or jar, *viz.* half a degree; but the plate's capacity, now it lies upon a proper plane, is above 100 times greater than if it stood insulated in the air; or, which is the same thing, it acquires 100 times more electricity from the jar or conductor. It naturally follows, that when the metal plate is removed from the proper plane, its capacity being lessened so as to remain equal to the 100th part of what it was before, the intensity of its electricity must become 50°, since the intensity of the electricity in the jar or conductor was half a degree.

If a small quantity of electricity, applied to the metal plate of the condenser, enables it to give a strong spark, it may be asked, What would a greater quantity do? Why, nothing more. Because, when the electricity communicated to the metal plate is so strong as to overcome the small resistance of the inferior plane, it will be dissipated.

It is easy to understand, that if the metal plate of the condenser can receive a good share of electricity from a Leyden jar or ample conductor, however weakly electrified, it cannot receive any considerable quantity of it from a conductor of small capacity; for this conductor cannot give what it has not, except it were continually receiving a stream, however small, as is the case with an atmospherical conductor, or with the conductor of a machine which acts very weakly, but continues in action. In those cases it has been observed, that a considerable time is required before the metal plate has acquired a sufficient quantity of electricity.

As an ample conductor, weakly electrified, imparts a considerable quantity of electricity to the metal plate of the condenser, so when this plate is afterwards separated from its plane, the electricity in it appears much condensed and vigorous; when the same plate contains a small quantity of electricity, such as cannot give a spark or affect an electrometer, that electricity may be rendered very conspicuous by communicating it to another small plate or condenser.

Mr. *Cavallo* first thought of this improvement, by reasoning on Mr. *Volta*'s experiments. He made a small metal plate not exceeding the size of a shilling: this second condenser is of great use in many cases, where the electricity is so small as not to be at all, or not clearly observable, by one condenser only, as has been fully proved. Sometimes the usual metal plate of a condenser acquires so small a quantity of electricity, that being afterwards taken from the inferior plane, and presented to an extremely sensible electrometer, made by Mr. *Cavallo*, it did not affect it. In this case, if the said plate thus weakly electrified was made to touch the other small plate properly situated, and was afterwards brought near an electrometer, the electricity was then generally stronger than was sufficient merely to ascertain its quality.

Now, if by the help of both condensers, the intensity of the electricity has been augmented 1000 times, which is by no means an exageration, how weak must then be the electricity of the body examined! how small the quantity of electricity that is produced by rubbing a piece of metal with one's hand! since, when it is condensed by both condensers, and then communicated to an electrometer, it will hardly affect that instrument, and yet is sufficient to afford conviction, that the metal can be electrified by the friction of a person's hand.

Before the discovery of the condenser, and Mr. *Cavallo*'s very sensible electrometer, we were far from being able to discover such weak excitations; whereas, at present, we can observe a quantity of electricity incomparably smaller than the smallest observable at those times.

CHAP. XVIII.

OF THE METHODS OF MANIFESTING THE PRESENCE, AND ASCERTAINING THE QUALITY OF NATURAL OR ARTIFICIAL ELECTRICITY.

Mr. *Canton* was the first person who constructed an electrometer, or instrument capable of shewing what was then considered as a small quantity of electricity. This instrument consisted of two small balls of pith of elder, or of cork, fastened to the two extremities of a linen thread, the middle of which was fastened to an oblong wooden box, in which the thread and balls were kept when not actually in use.

Mr. *Cavallo* found, in the course of his experiments, that these were not sufficiently sensible; and that a small quantity of power, being diffused through the box, thread, and balls, had not sufficient power to separate the balls.

To obviate this, Mr. *Cavallo* made the electrometers very short; suspended each ball by a separate piece of silver wire, the upper part of which was formed into a loop, moving in a ring of wire; this he inclosed in a bottle; from whence it acquired the name of the *bottle electrometer*.

DESCRIPTION OF MR. CAVALLO'S BOTTLE ELECTROMETER.

The principal part of this instrument is a glass tube, C D M N, *plate* 4, *fig.* 76, cemented at the bottom into the brass piece, A B, by which part the instrument is to be held, when used for the atmosphere; and it also serves to screw the instrument into its brass case, A B C. The upper part of the tube C D M N, is shaped tapering to a small extremity, which is entirely covered with sealing-wax; into this tapering part a small tube is cemented, the lower extremity, being also covered with sealing-wax, projects a small way within the tube, C D M N; into this smaller tube a piece of wire is cemented, which with its under extremity touches the flat piece of ivory, H, fastened to the tube by means of a cork; the upper extremity of the wire projects about a quarter of an inch above the tube, and screws into the brass cap, E F, which cap is open at the bottom, and serves to defend the waxed part of the instrument from rain, &c.

I M and K N are two narrow slips of tin-foil, stuck on the inside of the glass C D M N, and communicating with the brass bottom, A B. They serve to convey that electricity, which, when the balls touch the glass, is communicated to it, and being accumulated, might disturb the free motion of the balls.

To use this instrument for artificial electricity, electrify the brass cap by an electrified substance, and the divergence or convergence of the balls of the electrometer, at the approach of an excited electric, will shew the quality of the electricity. The best manner to electrify this instrument is, to bring excited wax so near the cap that one or both of the corks may touch the side of the bottle, C D M N; after which they will soon collapse and appear unelectrified. If now the wax is removed, they will again diverge, and remain unelectrified positively.

When this electrometer is to be used to try the electricity of the fogs, air, clouds, &c. the observer is to do nothing more than unscrew it from its case, and hold it by the bottom, A B, to present it to the air a little above his head, so that he may conveniently see the balls, P, which will immediately diverge, if there is any electricity; *i. e.* whether positive or negative may be ascertained, by bringing an excited piece of sealing-wax or other electric towards the brass cap, E F,

OF MR. DE SAUSSURE'S BOTTLE ELECTROMETER.*

The electrometer of Mr. *De Saussure* is nearly the same as that of Mr. *Cavallo*'s. The following are the most material circumstances in which they differ; first, the fine wires by which the balls are suspended should not be long enough to reach the tin-foil which is pasted on the inside of the glass, because the electricity, when strong, will cause them to touch this tin-foil twice consecutively, and thus deprive them in a moment of their electricity. To prevent this defect, and yet give them a sufficient degree of motion, it is necessary to use larger glasses than those that are

* This electrometer may be used instead of the condenser of M. *Volta*, by only placing it on a piece of oiled silk, somewhat larger than the base of the instrument; but, in this case, it is the base, and not the top of the instrument, which must be brought into contact with the substance whose electricity is to be explored.

By this instrument, it is easy to ascertain the degree of conducting power in any substance. For example, if it is placed on an imperfect conductor, as dry wood or marble, and if the instrument is electrified strongly, and afterwards the top is touched, the electricity will appear to be destroyed; but, on lifting up the instrument by the top, the balls will again open, because the imperfect conductor formed with the base a kind of electrophorus, by which the electric fluid was condensed and lost its tension, till the perfect conductor was separated from generally applied to Mr. *Cavallo*'s electrometer; two or three inches diameter will be found to answer the purpose very well. But, as it is necessary to carry off the electricity which may be communicated to the inside of the glass, and thus be confounded with that which belongs to those substances that are under examination; four pieces of tin-foil should be pasted on the inside of the glass: the balls should not be more than one-twentieth of an inch diameter, suspended by silver wire, moving freely in holes nicely rounded. The bottom of the electrometer should be of metal; for this renders it more easy to deprive them of any acquired electricity, by touching the bottom and top at the same time.* See *plate* 1, *fig.* 11, 12, 13.

the imperfect one; whereas, if the conductor had been more perfect, it would have been deprived of its electricity immediately on the application of the hand.

It is easy to discover also by this instrument the electricity of any substance, as of cloaths, hair of different animals, &c. For this purpose, it must be held by the base, and the substance rubbed briskly, only once, by the ball of the electrometer; the kind of electricity may be ascertained in the usual manner. It is proper, however, to observe here, that as the top of the electrometer acts in this case as an insulated rubber, the electricity it acquires is always contrary to that of the rubbed body.

* Voyage dans les Alpes par *H. B. De Saussure,* Tom. second.

In order to collect a great quantity of electricity from the air, the electrometer is furnished with a pointed wire fifteen inches or two feet long, which unscrews in three or four pieces, to render the instrument more portable; see *plate* 1, *fig.* 11. When it rains or snows, the small parapluie, *plate* 1, *fig.* 13, is to be screwed on the top of the instrument, as by this its insulation is preserved, notwithstanding the rain.

This instrument indicates not only the electricity of fogs, but that also of serene weather, and enables us to discover the kind of electricity which reigns in the atmosphere; and to a certain degree to form an estimate of its quantity; and that under two different points of view, the degree of intensity, and the distance from the earth at which it first begins to be sensible.

A conductor * exhibits signs of electricity, only when the electric fluid is more or less condensed in the air than in the earth. Though the air resists the passage of the electric fluid, it is not absolutely impermeable to it; it suffers it to pass gradually, and generally with more ease in proportion as its mass or thickness is less. It is, therefore, interesting to discover at what height

* A conductor raised for the purpose of making atmospherical experiments, is meant here.

it is necessary to be elevated, in order to find a sensible difference between the electricity of the earth, and that of the air. A very sensible difference may be generally discovered by this instrument, at the distance of four or five feet from the ground; sometimes it may be seen if the instrument is placed even on the ground, while at others, it must be raised seven or more feet, before the balls will open; sometimes, though seldom, this height is not sufficient. This distance is generally greatest when the electricity is the strongest, though necessarily modified by a variety of circumstances; some of which are known, as the degree of dryness or humidity of the air; and others are unknown.

The degree of intensity at a given height may be discovered thus; raise the electrometer, and judge by the divisions which are placed on the edge thereof the degree of their divergence. To find the relation between this degree of divergence and the force of the electricity, M. *De Saussure* took the following method: as he could not with certainty double or triple a given quantity of electricity; yet, as a given force may be reduced one-half, a fourth, or eighth, &c. by dividing between two equal and similar bodies the electricity contained in one, he took two of his unarmed electrometers, which were as similar as possible, and electrified one of them, so that the balls separated precisely six lines; he then touched the top thereof by the top of that which was not electrified; in an instant the electricity was equally divided between them, as was evident by the divergence of the balls, which was four lines in each; consequently, a diminution of half the density had only lessened the divergence one-third. One of these electrometers was then deprived of its electricity, and was afterwards brought in contact with the other, as before; the remaining electricity divided itself again between them, and the balls fell from four to twenty-eight lines, nearly in the same proportion as before; in the third operation, they fell to nineteen; in the fourth, to one; where he was obliged to stop, as there was not now sufficient force in the fluid to pass from one electrometer to the other, and distribute itself uniformly between them. The same experiment repeated several times gave very nearly the same results. Negative electricity decreased also in the same proportion as the positive. The following table may, therefore, be considered as giving a general, though not exact idea *(un apercu)* of the increase in force which corresponds to different degrees of divergence in the balls; it is only calculated to every fourth of a line. The force of electricity is always expressed by whole numbers, as it would be ridiculous to put a greater degree of exactness in the numbers than is to be found in the experiments which form the basis of the calculation.*

Distance of the balls in fourths of a line.			Corresponding forces of electricity.
1	——	——	1
2	——	——	2
3	——	——	3
4	——	——	4
5	——	——	5
6	——	——	6
7	——	——	8
8	——	——	10
9	——	——	12
10	——	——	14
11	——	——	17
12	——	——	20
13	——	——	23
14	——	——	26
15	——	——	29
16	——	——	32
17	——	——	36

* M. *De Saussure,* in a long note, anticipates the objections that may be made to the foregoing method of estimating the force of electricity; but, as at the most they only shew that this science is at present in a state of considerable imperfection, it will be unnecessary to take notice of them here.

Distance of the balls in fourths of a line.			Corresponding forces of electricity.
18	——	——	40
19	——	——	44
20	——	——	48
21	——	——	52
22	——	——	56
23	——	——	60
24	——	——	64

Those who are desirous to carry this measure of the electric force further, may do it by having similar electrometers constructed, but made upon a larger scale, and with heavier balls, which would only separate one line, with the degree of electricity that makes the smaller ones diverge six lines; these would consequently measure a force 1024 times greater than that which forms the unity of the preceding table; and thus, by degrees we may be enabled to discover the ratio of the strongest discharge of a great battery, or perhaps even of thunder itself, to that of a piece of amber, which only attracts a bit of straw.*

* The consideration of the repulsive force is not sufficient to discover the absolute force of an explosion or electrical discharge. For Mr. *Volta* has shewn, that the force of a discharge depends principally on the quantity of the electric fluid which passes from one body to another. Now, the repulsive force of the electrometer only indicates the ratio of this quantity in equal and similar bodies, and which are also similarly situated.

Another alteration of the bottle electrometer has been lately invented by the Rev. Mr. *Bennet*, which in point of sensibility is far superior to any hitherto contrived.

If equal quantities of the electric fluid were imparted to two unequal and separate conductors, the electric fluid, being less condensed on the largest, would act with the least force on the electrometer; though it is probable, the force of the discharge in the two conductors would be equal. The repulsive force serves, however, to shew what Mr. *Volta* calls the *electrical capacity* of a body, the quantity of the electric fluid it actually contains, or is capable of containing. To effect this, and have points of comparison, we should use light metallic balls of different sizes, suspended by silk threads. One of these balls, unelectrified, being brought into contact with the substance whose electricity is to be explored, will diminish the tension or repulsive force of this substance; and the quantity diminished by the contact of the ball will give the ratio of the capacity of this substance with that of the ball. Let us suppose a Leyden jar uninsulated, but so concealed that only the knob is visible, and we are therefore ignorant of its size, and the strength of the shock it will give. Let the top of M. *De Saussure*'s electrometer be in contact with the knob of the jar, and the balls of the electrometer separate six lines: from this solitary fact, we shall gain no information relative to the force of the shock; because, if the jar is very large, this degree of tension will give a very painful sensation; when, if it is very small, with the same indicated tension, the sensation may be almost imperceptible. But, if I bring a ball of a foot diameter in contact with the knob of the jar, and after having thus taken a part of the fluid therefrom, the electrometer is again put in contact with the knob thereof, the remaining quantity of repulsive force will shew the relation between its contents and that of the globe of metal, and by this means the intensity of its charge.

DESCRIPTION OF THE REV. MR. BENNET'S GOLD LEAF ELECTROMETER.* *Plate* 1, *fig.* 10.

The foot, A, may be made of metal or wood, and about three inches high, that there may be convenient room to move the instrument, without the hands touching the glass part, B.

The cylindrical glass, B, in which the gold leaf is suspended, may be about five inches high, and two inches diameter.

The cap, C, is made of metal, and flat on the top, that the various substances whose electricities are to be examined may be conveniently placed upon it.

The diameter of the cap is about an inch more than that of the glass, and its rim is about an inch deep, hanging parallel to the glass, to keep it clean and dry: within this, is another circular rim, about half as broad as the other, made to go over or within the glass, and is therefore lined or covered with leather, or other soft substance, to make it fit close; and thus the cap may be easily taken off to repair any accident happening to the gold leaf. Within this rim, and in the center of the cap, a tube is fixed wherein a peg is placed. To this peg, which is made round at one end and

* See his very valuable work, entitled "New Experiments on Electricity."

flat at the other, two slips of gold leaf are fastened with paste, gum-water, or varnish.

If gold leaf be used, it may be shorter than silver leaf. The gold is the most sensible, but the silver is easier to cut, and less liable to be torn by any accident.

Two pieces of polished tin-foil are fastened with varnish on opposite sides of the internal surface of the glass, where the gold leaf may be expected to strike, and are connected with the foot of the electrometer. These slips not only carry off the superfluous electricity, but serve other important purposes.*

The upper end of the glass is covered and lined with sealing-wax as low at least as the outer rim, to render its insulation more perfect.

The following experiments shew the great sensibility of this little instrument.

1. Powdered chalk was put into a bellows, and blown upon the cap; it was electrified positively by the stream of chalk, when the nozzle of the bellows was only six inches distant from the cap; but the same stream electrified it negatively at the distance of three feet. In this experiment, the quality of the electricity is changed from positive to negative, by dispersing or widening the stream,

* Some gold or silver leaf, a cushion, a cutting knife, and wooden forceps, such as are used by the gold-beaters, are very useful articles for replacing the slips, when necessary. EDIT.

and making it pass through a longer track of air; it is also changed, by passing the stream through a bunch of fine wires, silks, or feathers placed upon the nozzle of the bellows; it is negative, when blown from a pair of bellows, the iron pipe being taken off to enlarge the stream. This last experiment seems to answer best in damp weather. The positive electricity generally remains; but in the negative, the leaf gold collapses as soon as the cloud of chalk is passed.

2. A piece of chalk drawn over a brush, or powdered chalk put into a brush and projected on the cover, electrified it negatively. The electricity was not permanent.

3. Powdered chalk blown with the mouth or a pair of bellows, *plate* 1, *fig.* 19, from a plate placed upon the cover, gave a permanent positive electricity. If a brush is placed upon the cover, and a piece of chalk is drawn over it, when the hand is withdrawn, the leaf gold gradually expands with positive electricity, as the cloud of chalk disperses.

4. Powdered chalk falling from one plate to another, placed on the instrument, electrified it negatively. Many other experiments have been tried, as projecting it from a goose wing, chalking the edges of a book, &c. The instrument being placed in a dusty road, the dust struck up with a stick near it, electrified it positively; wheat flour

and red lead gave a strong negative electricity, in all cases where the chalk gave a positive.

5. Place a metal cup upon the cap with a red hot coal in it, *plate* 1, *fig.* 20, a spoonful of water thrown upon the coal electrifies the cup negatively. If a bent wire be placed upon the cover, with a piece of paper fastened to it, to increase its surface, it will exhibit the positive electricity of the ascending vapour, when introduced into it. The electricity of rain may probably be illustrated by pouring water on hot coals placed in an insulated cullender; the ascending vapour is positive, the descending drops are negative.

6. The sensibility of this instrument may be increased, by placing a candle upon the cap; by this means a cloud of chalk, which would but just open the leaf gold before, will cause them to strike the sides for a long time together, and the electricity is now communicated so strong, that the leaves will be repelled by a stick of excited wax at ten or twelve inches distance. A cloud of chalk made in one room will electrify this instrument brought from another room, and at a considerable distance.

A thunder-cloud passing over the instrument, caused the leaf gold to strike the sides at every flash of lightning. No sensible electricity has been discovered by it on the explosion of gunpowder, or the projection of smoke, or flame over it.

Excited sealing-wax will often make the leaf gold strike the sides of the glass more than twelve times; when the sealing-wax recedes, it will strike it again, nearly the same number of times; but, if the approach is quicker than the recession, the number of times will sometimes be greater.

If a small lantern, with a candle in it, be placed upon the cap of the electrometer, and exposed to the air in an open place, or not too near high buildings or trees, it seldom fails to render the atmospheric electricity very sensible.

If the electrometer be charged with a small quantity of electricity, and the sharpest pointed needle, or edge of a razor, be brought within the least visible distance towards the cap, it will not draw off the electricity; but flame draws it off at a considerable distance.

The last experiment shews that sharp points, or edges, need not be avoided in the construction of this instrument, or of the doubler to be spoken of hereafter, or atmospheric apparatus; and that flame is better than a pointed wire for the purpose of collecting atmospheric electricity.

A small pin was fastened upon the end of a stick of sealing-wax, and charged with electricity, which was communicated from the pin to a metallic insulated conductor, fifteen inches in diameter and seven feet long; whose surface was therefore prodigiously larger than that of the pin, yet its electricity caused a very sensible divergency of the gold leaf: thus, not only shewing the sensibility of the electrometer, but the amazing divisibility and expansibility of this wonderful fluid.

Besides the method of discovering small quantities of electricity by means of very delicate electrometers, two methods have been communicated to the philosophical world, by which such quantities of electricity may be rendered manifest, as could not be perceived by other means. The first of these methods is an invention of Mr. *Volta*, called the *condenser of electricity*; the second is an invention of the Rev. Mr. *Bennet*, called the *doubler of electricity*.

Mr. *Volta*'s condenser, which has been already described in his own words, consists of a large smooth metal plate, furnished with an insulating handle, and a semi-conducting or imperfect insulating plane. See D and E, *plate* 11, *fig*. 10.

To examine a weak electricity with this apparatus, as that of the air in calm and hot weather, which is generally too weak to be rendered sensible by an electrometer, place the metal plate upon the semi-conducting plane, letting a wire, or some other conducting substance, be connected with the metal plate, and extended in the open air, to absorb its electricity; then, after a certain time, the metal plate must be separated from the same conducting plane, and being presented to an electrometer, will electrify it more than if it had not been placed on such a plane; and this, because the metal plate, while standing contiguous to the semi-conducting plane, will absorb and retain a much greater quantity of electricity than it could either absorb or retain when separate.

The office of this apparatus is not to manifest a small quantity of electricity, but to condense an expanded quantity into a small space. But Mr. *Bennet's* doubler is designed to multiply, by repeatedly doubling a small, and otherwise unperceivable quantity of electricity, till it becomes sufficient to affect an electrometer and give small sparks.

BENNET'S OR NICHOLSON'S DOUBLER.

Plate 1, *fig.* 9, represents the apparatus, supported on a glass pillar six inches and an half long.

It consists of the following parts: two fixed plates of brass, A and C, are separately insulated, and disposed in the same plane, so that a revolving plate, B, may pass very near them, without touching. Each of these plates is two inches in diameter; and they have adjusting pieces behind, which serve to place them accurately in the required position. D is a brass ball, likewise of two inches diameter, fixed on the extremity of an axis that carries the plate, B. Besides the more essential purpose this ball is intended to answer, it is so loaded within, on one side, that it serves as a counterpoise to the revolving plate, and enables the axis to remain at rest in any position. The other parts may be distinctly seen in *fig*. 9, *No*. 2. The shaded parts represent metal, and the white represent varnished glass. O N is a brass axis, passing through the piece, M, which last sustains the plates A and C. At one extremity is the ball, D, already mentioned; and the other is prolonged by the addition of a glass stick, which sustains the handle, L, and the piece, G H, separately insulated. E, F, are pins rising out of the fixed plates, A and C, at unequal distances from the axis. The cross piece, G H, and the piece, K, lie in one plane, and have their ends armed with small pieces of harpsichord wire, that they may perfectly touch the pins, E, F, in certain points of the revolution. There is likewise a pin, I, in the piece, M, which intercepts a small wire proceeding from the revolving plate, B.

The touching wires are so adjusted, by bending, that when the revolving plate, B, is immediately opposite the fixed plate, A, the cross piece, G H, connects the two fixed plates, at the same time that the wire and pin at I form a communication between the revolving plate and the ball. On the other hand, when the revolving plate is immediately opposite the fixed plate, C, the balls become connected with this last plate, by the touching of the piece K against F; the two plates, A and B, having then no connexion with any part of the apparatus. In every other position, the three plates and the ball will be perfectly unconnected with each other.

When the plates, A and B, are opposite to each other, the two fixed plates, A and C, may be considered as one mass; and the revolving plate, B, together with the ball, D, will constitute another mass. All the experiments yet made concur to prove, that these two masses will not possess the same electric state; but that, with respect to each other, their electricities will be *plus* and *minus*. These states would be simple, and without any communication, if the masses were remote from each other; but as that is not the case, a part of the redundant electricity will take the form of a charge in the opposed plates, A and B. From other experiments, I find that the effect of the compensation on plates opposed to each other, at the distance of one-fortieth part of an inch, is such that they require, to produce a given intensity, at least one hundred times the quantity of electricity that would have produced it in either, singly and apart. The redundant electricities in the masses under consideration will therefore be unequally distributed: the plate, A, will have about ninety-nine parts, and the plate, C, one;

and, for the same reason, the revolving plate, B, will have 99 parts of the opposite electricity, and the ball, D, one. The rotation, by destroying the contacts, preserves this unequal distribution, and carries B from A to C, at the same time that the tail, K, connects the ball with the plate, C. In this situation, the electricity in B acts upon that in C, and produces the contrary state by virtue of the communication between C and the ball; which last must therefore acquire an electricity of the same kind with that of the revolving plate. But the rotation again destroys the contact, and restores B to its first situation opposite A. Here, if we attend to the effect of the whole revolution, we shall find that the electric states of the respective masses have been greatly increased; for the ninety-nine parts in B remain, and the one part of electricity in C has been increased so as nearly to compensate ninety-nine parts of the opposite electricity in the revolving plate B, while the communication produced an equal mutation in the electricity of the ball. A second rotation will, of course, produce a proportionable augmentation of these increased quantities; and a continuance of turning will soon bring the intensities to their maximum, which is limited by an explosion between the plates.

If one of the parts be connected with an electrometer, more especially that of *Bennet*, these effects will be very clearly seen. The spark is usually produced by a number of turns, between eleven and twenty; and the electrometer is sensibly acted upon by still fewer. When one of the parts is occasionally connected with the earth, or when the adjustment of the plates is altered, there are some variations in the effects, not difficult to be reduced to the general principles, but sufficiently curious to excite the meditations of persons the most experienced in this branch of natural philosophy: an attention to brevity, however, renders it necessary to forbear enlarging upon them. If the ball be connected with the lower part of *Bennet's* electrometer, and the plate, A, with the upper part, and any weak electricity be communicated to the electrometer, while the position of the apparatus is such that the cross piece, G H, touches the two pins; a very few turns will render it perceptible. But here, as well as in the common doubler, the effect is rendered uncertain by the condition, that the communicated electricity must be strong enough to destroy and predominate over any other electricity the plates may possess. I scarcely need observe, that if this difficulty should hereafter be removed, the instrument will have great advantages as a multiplier of electricity in the facility of its use, the very speedy manner of its operation, and the unequivocal nature of its results.

MR. BROOKE'S ELECTROMETER FOR CHARGED JARS AND BATTERIES.*

This article might have been introduced with greater propriety in the beginning of this work; but, as the plate was then altering, to render the drawing conformable to that given by Mr. *Brooke* himself, I chose rather to postpone it till the plate was finished.

An accurate admeasurement of the quantities of electricity is among the desiderata in this branch of philosophy; and, as the electrometers which have heretofore been invented have in that respect been found deficient, Mr. *Brooke* has endeavoured to supply this deficiency by a new instrument.

Plate 5, *fig*. 95, exhibits the electrometer in miniature, as it appears when it is ready to be used.

Fig. 96, B, is an arm, the ball of which is to be laid to make a communication with a battery.

Fig. 97, is the lower part of the electrometer, separate from the upper part.

The arms, F H, f k, *fig*. 97, are, when in use, to be placed as much as possible out of the atmosphere of a jar, battery, &c.

* *Brooke*'s Miscellaneous Experiments and Observations on Electricity.

The dial plate, *fig.* 96, is divided into 90 equal parts; the index of this plate is carried once round when the arm, B C, has moved through 90 degrees, or a quarter of a circle. That motion is given to the index by the repulsive power of the charge acting between the ball D and the ball B.*

The arm, B C, being repelled, shews when the charge is increasing, and the arm, F H, shews what this repulsive power is between two balls of this size in grains, according to the number the weight rests at when lifted up by the repulsive power of the charge: at the same time the arm, B C, points out the number of degrees to which the ball, B, is repelled; so that, by repeated trials, the number of degrees, answering to a given number of grains, may be ascertained, and a table formed from these experiments, by which means the electrometer, *fig.* 96, may be used without that of *fig.* 97.

Mr. *Brooke* thinks that no glass, charged, as we call it, with electricity, will bear a greater force than that whose repulsive power, between two balls of the size he used, is equal to sixty grains; that in very few instances it will stand sixty grains weight; and he thinks it hazardous to go more than forty-five grains.

Hence, by knowing the quantity of coated surface, and the diameter of the balls, we may be

* Phil. Trans. vol. lxxxii. p. 384.

enabled to say, so much coated surface, with a repulsion between balls of so many grains, will melt a wire of such a size, or kill such an animal.

Mr. *Brooke* also thinks, that he is not acquainted with all the advantages of this electrometer; but that it is clear, it speaks a language which may be universally understood, which no other will do; for, though other electrometers will shew whether a charge is greater or less, by an index being repelled to greater or smaller distances, or by the charge exploding at different distances, yet the power of the charge is by no means ascertained: but this electrometer shews the force of the repulsive power in grains; and the accuracy of the instrument is easily proved, by placing the weights on the internal ball, and seeing that they coincide with the divisions on the arm, F H, when the slide is removed to them.

CHAP. XIX.

OF ATMOSPHERICAL ELECTRICITY.

It is now universally acknowledged by every philosopher, that the electric fluid is disseminated through the whole atmosphere: it is also known, that the motion of this fluid is restrained when it acts in dense air, but it moves with the greatest liberty in a vacuum or rarefied air, as in an exhausted receiver. Therefore at a great height, where the air is equally, if not more rarefied than in our receivers, its motion must be exceeding free, and hence capable of the greatest effects; because it can be moved from one place to another with extreme ease and rapidity, and in great quantities: and if, as many philosophers believe, the electric fluid is that ether or subtile matter which fills the intervals between the planets, how great must be the force of an agent which fills these immense spaces! Be this as it will, we know that the upper strata of air are filled with this fluid, and that it moves there freely.

Again, we know that water, whether in substance or in vapour, is a conductor of electricity; that in proportion as air is loaded with it, it resists less the motion and diffusion of the electric fluid;

consequently, if vapour rises to a great height, it becomes a conductor and canal of communication between this immense reservoir, this ocean of free electric fluid, and the entire mass of our globe. If then this fluid is more restrained at one part of our globe, than it is in corresponding parts of the higher regions, the vapours will be the medium to restore the equilibrium. But this equilibrium will not last long, for it is natural to suppose this immense fluid subject to a flux and re-flux, currents, &c. which will alter its local density. Thus also this fluid, which is contained in our globe, cannot be long uniformly spread through its mass, as there are ten thousand agents, which will either accumulate or rarefy it; consequently, vapour will scarce ever rise, without serving as a vehicle to maintain the equilibrium between our globe and the fluid in the higher regions of the atmosphere.

This theory is so natural a consequence of the most immediate and certain principles of electricity, that it seems almost superfluous to confirm it by the phenomena which it explains. It is the only one that accounts for the following fact, that vapours never rise to a great height without producing the most terrible meteors. All considerable volcanic productions are accompanied with lightning. The fire which rises from the earth seems to light that of heaven. The column of vapour which proceeds from the bowels of a volcano is continually traversed by lightning,* which sometimes seems to proceed from the higher regions, sometimes from the column itself. Hail, which necessarily supposes the ascension of vapour to a considerable height, is always accompanied with electricity. The aurora borealis is also electrical; its light seems to be produced by the electric fluid, at the instant it is condensed in passing in the columns of elevated vapour.

Waterspouts, whirlwinds, and even earthquakes, are in a great measure the effects of torrents of the electric matter, attracted from the higher regions by torrents of vapour. In a word, can the electricity of the clouds be attributed to a more natural or probable cause?†

For the subject of this chapter we are principally indebted to *P. Beccaria*, who has for many years accurately observed the various changes in the electricity of the atmosphere, and their relation to the other phenomena of the weather. His apparatus was admirably well adapted for this purpose, and superior to any thing we are at present acquainted with for imitating easily and at all times the electricity of the air. It not being at

* The younger *Pliny* observed these lightnings in the eruption which killed his uncle. Sir *William Hamilton* has also observed them several times.

† *Saussure's* Essais sur l'Hygrometrie, p. 275.

first suspected, that electricity was so intimately blended with every operation of nature, as it is now known to be, the labourers in this part are of course very few; the principal are *P. Beccaria*, Mr. *Ronayne*, and Mr. *Cavallo*.

I have extracted and methodized the results of the observations made by *P. Beccaria*, introducing occasionally those made by others; that the reader might be in possession of the most material facts, and excited to investigate and pursue with attention this delicate and important subject; for, indeed, little certainty can be expected from any system of meteorology, where the action of the principal agent is not particularly considered and attended to.

The apparatus used by *P. Beccaria*, for investigating the electricity of the atmosphere, was an iron wire, which he terms an exploring wire, 132 feet long. It was fixed at one end to a pole raised over the chimney, the other end was fastened to the top of a cherry-tree. The extremities of the wire were insulated, and covered with a small umbrella of tin. Another wire was brought from this, through a thick glass tube coated with sealing-wax, into the room; by which means, continual information of the state of the electricity in the exploring wire was obtained. He connected with this wire a small slip of metal, on each side of which was a small pith ball, one line in diameter;

the balls were suspended by silk threads, sixteen lines long.

Air-balloons will probably enable us to discover with certainty the electricity of the different strata of the atmosphere. M. *De Saussure* has already made the experiment with a balloon made of taffety, containing 200 cubic feet of air, and which was raised by the heat from the flame of spirit of wine; with this, in cloudy but calm weather, he obtained a strong positive electricity.*

The electricity, in serene weather, generally makes each of the balls diverge about six lines; when it is very strong, they will diverge fifteen or twenty degrees from the metal plate; when weak, the divergence is very small.

In serene weather, the wire, after being touched, will take a minute or longer before it again shews signs of electricity; though, at other times, it will become electrified in the space of a second.

The electricity during serene weather is always positive: there are few instances in which it is negative, and then it is brought over by the wind from some part of the atmosphere, perhaps very distant from the place of observation, where there is either fog, snow, rain, or clouds. The whole series of observations which *P. Beccaria* has made

* *Faujas de St. Fond,* Description des Experiences Aerostatiques, tom. ii. p. 271.

confirm this position. He seems to have met with only three or four instances to the contrary.

Dr. *Franklin* has observed, that the clouds are sometimes negative, which is certainly true; because they will at times absorb, at and through the apparatus, a large and full bottle of positive electricity, of which the apparatus could not have received and retained the hundredth part. And it is easy to conceive, how a strongly charged large positive cloud may reduce smaller clouds to a negative state.

The electricity of the atmosphere is very much connected with the state of the air, as to moisture and dryness; so that it is necessary to attend to the hygrometer, in order to form a proper judgment of the different degrees of electricity at different times. That invented by Mr. *Coventry*, which is made of hatters paper, will answer best; it is very sensible, absorbs moisture soon, and parts with it easily.* Comparative observations may also be made with it. It is also necessary to place a thermometer near the hygrometer, to ascertain what quantity of moisture the air can keep in solution with a given degree of heat; though this object will more probably be obtained by observing accurately the quantity of moisture

* The whalebone hygrometer, as lately constructed by M. *De Luc*, is undoubtedly the most perfect of any hitherto made. See my Edition of *Adams*'s Lectures, vol. iv. p. 569. EDIT.

evaporated from a given surface at different times. It is also to be observed, that the different degrees of density in the air will affect the quantity of moisture which is retained in the air.

The moisture in the air is the constant conductor of the atmospheric electricity during clear weather; and the quantity of electricity is proportioned to the quantity of moisture which surrounds the exploring wire; except there is so much as to lessen the exactness of the insulation of the wire and of the atmosphere. In a dry state of the air, it will sometimes be above a minute before the balls will manifest any electricity after the wire has been touched; though, in a damper state, a second will scarce elapse, before rapid oscillations of the balls may be observed between the finger and the plate of brass to which they are affixed.*

The electricity, when the weather clears up, is always positive. When the weather is clearing up, and becomes dry quickly, the electricity rises to a great degree of intensity, and affords frequent opportunities for repeating the observations. It sometimes happens, that the electricity

* In making observations on the electricity of the atmosphere in clear weather, it is essential to repeat them very frequently; *i. e.* to observe the velocity with which the electricity rises after it has been annihilated; which *P. Beccaria* generally estimated by the number of seconds elapsed before the balls began to manifest their electricity.

caused by the clearing up of the weather continues in its state of intensity for a long while; and also, after being interrupted, it begins afresh. These accidents seem to be owing to the electricity being brought over by the wind from great distances.

P. Beccaria says, that whenever he observed that the thick low clouds which were over his head began to break, and the rare even clouds, which are above the former, became dilated, that the rain ceased and the balls diverged with positive electricity, he always wrote down, *certain tendency to clear weather*.

Prior *Ceca* says, that a strong positive electricity after rain is an indication that the weather will continue fair for several days. If the electricity is weak, it is a sign that the fair weather will not last the whole day; but that it will soon be cloudy, and even rain.

If, when the sky grows cloudy over the place of observation, and a high cloud is formed, without any secondary clouds under it, and it is not an extension of a cloud which drops rain elsewhere, either no electricity takes place, or it is positive.

If the clouds which are gathering are shaped like locks of wool, and keep moving first nearer to, and then separating from each other; or, if the general cloud which is forming lies very high, and is stretched downwards like descending smoke, then positive electricity commonly takes place, which is more or less strong in proportion to the quickness with which this cloud forms; and it foretels the greater or less quantity and velocity of rain or snow which is to follow.

When a thin, even, and extensive cloud is forming, which darkens the sky and turns it into a grey colour, a strong and repeated positive electricity takes place; but, in proportion as the gathering of the cloud slackens, this electricity lessens, or even fails. On the contrary, if the rare extensive cloud is gradually formed of smaller clouds, like locks of wool, which are continually joining to and parting from each other, the positive electricity commonly continues.

Low and thick fogs, especially when as they rise the air above them is free from moisture, carry up to the exploring wire an electricity which will give small sparks repeatedly, and produce a divergence of the balls from 20° to 25°, or even 30°. If the fog grows sluggish, and continues round the exploring wire, the electricity soon fails; but, if it continues to rise, and another cloud succeeds, it electrifies again the wire, though less than before. Sky-rockets sent through such thick, low, and continued fogs, often afford signs of electricity. *P. Beccaria*, under any one of the circumstances above-described, never met with an instance of negative electricity; except perhaps once, when he sent a sky-rocket, to which a string was fixed, through a low thick fog; though he had afterwards every reason to think, that he had mistaken *a false little star for a true one*.

Mr. *Ronayne* observed, that the air in Ireland was generally electrified in a fog, and even in a mist, and that both day and night, but principally in winter; seldom in summer, except from positive clouds, or cool fogs. The electricity of the air in a frost or fog is always positive. He says, that he has often observed, during what seemed the passing of one cloud, successive changes from negative to positive, and from positive to negative.

N. B. Most fogs have a smell very like an excited glass tube.

Mr. *Henley* has shewn, that fogs are more strongly electrified in, or immediately after a frost, than at other times; and that the electricity in fogs is often the strongest soon after their appearance.

Whenever there appears a thick fog, and at the same time the air is sharp and frosty, that fog is strongly electrified positively.

Though rain is not an immediate cause, yet he is inclined to think it was always a remote consequence of electricity in the atmosphere; and he generally found, that in two or three days after he had discovered the air to be strongly electrified, we had rain, or other falling weather.

If, in clear weather, a low cloud, which moves slowly and is considerably distant from any other, passes over the wire, the positive electricity generally grows very weak, but does not become negative; and when the cloud is gone, it returns to its former state. When many whitish clouds, like locks of wool, keep over the wire, sometimes uniting with, and then separating from each other, thus forming a body of considerable extent, the positive electricity commonly increases. In all the above circumstances, the positive electricity never changes to a negative one.

The clouds which lessen the electricity of the exploring wire are those which move; though those that are low seem also to have the same effect.

OF THE DIURNAL ATMOSPHERICAL ELECTRICITY.

In the morning, when the hygrometer indicates a degree of dryness equal to, or little less than that of the preceding day, an electricity takes place before the sun rises; which is manifested by junctions, adhesions, or even a divergence of the balls, and is proportioned to the dryness of the air, and the smallness of its difference from that of the preceding day. If this state of dryness does not obtain, no discernible electricity will be perceived before, or even for a little while after, the rising of the sun. As the air is generally damp in the night, electricity is seldom observed before the sun rises. During three months observations, *P. Beccaria* found the electricity before the sun rose only eighteen mornings; and from the whole of his numerous observations it appears, that the appearance of electricity in winter before sun-rise is more frequent than in summer, especially if the dampness from the hoar frost is prevented from affecting the apparatus.

In the morning, as the sun rises higher, the electricity, whether it began before sun-rise or only after, gradually increases. This gradual increase of the morning electricity begins sooner, if the hygrometer continues after sun-rise to indicate a greater degree of increasing dryness. The intensity and the rise of the electricity, after it has been annihilated by touching the exploring wire, lasts in serene days, in which no impetuous wind takes place and the hygrometer is stationary at the highest degree it has attained that day, till the sun draws near the place of its setting. When the sun is near setting, and in proportion as the hygrometer absorbs the moisture, the intensity of the daily electricity lessens.

Though the hygrometer may indicate equal degrees of dryness at twelve o'clock, in different days, yet the electricity will appear sooner after being destroyed on some days than on others; and this is in a great measure proportioned to the increase of heat. The electricity moreover commences on such days later in the morning, and falls sooner in the evening.

The friction of winds against the surface of the earth is not the cause of atmospheric electricity. Impetuous winds lessen the intensity of the electricity in clear weather. If they are damp, they lessen its intensity in proportion to the diminution they cause in the exactness of the insulation both of the wire and atmosphere.

OF THE ELECTRICITY PRODUCED BY THE EVENING DEW.

In cold seasons, if the sky is clear, little wind, and a great degree of increasing dryness, an electricity of considerable intensity arises after sun-set, as soon as the dew begins. The frequency of such electricity is moreover greater than that of the daily electricity, and it vanishes slowly.

In temperate or warm seasons, if the same circumstances as before-mentioned take place, an electricity entirely similar to the former arises as soon as the sun has set: only its intensity is not so constant; it begins with greater rapidity, and ends sooner.

If, under the above circumstances respectively, the general dryness of the air happens to be less, the electricity that rises in the evening when the dew begins is less in proportion to the diminutions of the exactness of the insulation of both the exploring wire and the atmosphere; but correspondently to the greater quantity of dew, the frequency of the electricity is greater.

The electricity of dew seems to depend on the quantity of dew, and to follow, in its various changes, proportions similar to those which take place between the electricity of calm mild rain, and that of rainy and stormy weather, and varies also according to the seasons.

As rain, showers, the aurora borealis, and the zodiacal light, have a tendency to appear for several successive days with the same characteristic accidents, so the electricity of dew seems to have as it were an inclination to appear for several evenings successively with the same characters.

Experiment ccxxxviii. Let the air in a well-closed room be electrified; that is to say, the moisture and other vapours diffused in it: then let a bottle filled with water colder than the air in the room, and insulated on a tube of glass, be raised pretty high in this room. Care must be taken to preserve the insulation of the glass with warm cloths. The electric signs that will arise in two threads suspended to such bottle, will exactly represent the electricity of dew; and they will exhibit the different manner after which this electricity takes place, according as the electrified vapours in the room are more or less rare, as the difference between the heat of the air in the room and that of the water in the bottle is less or greater, and the insulation of the bottle is more or less exact.

In a thunder storm, Mr. *Ronayne* observed, that the flashes would cause sudden changes. Sometimes the electricity would be extended, sometimes diminished, at other times increased, and sometimes even changed to the contrary again, though none was perceived before; it would come on suddenly with a flash of lightning. A large thunder cloud, when it darkens the hemisphere, does not produce so much electricity as a branch of it, or even as a common shower; and a storm does not go in a regular current of the wind, but obliquely and zig-zag, *viz.* it rains in that region from whence the storm is to proceed.

EXPERIMENTS AND OBSERVATIONS ON ATMOSPHERICAL ELECTRICITY, BY MR. CAVALLO.

These were principally made with an electrical kite, which will collect electricity from the air at any time. The power of this instrument resides in the string. The best method of making the string, is by twisting two threads of common twine with one of that copper thread which is used for trimming: a school-boy's kite with this string answers the purpose as well as any other. When a kite constructed in this manner was raised, Mr. *Cavallo* says he always observed the string to give signs of electricity, except once; the weather was warm, and the wind so weak, that the kite was raised with difficulty, and could hardly be kept up for a few minutes: afterwards, when the wind increased, he obtained as usual a strong positive electricity.

If this kite was raised at a time when there was any probability of danger from the great quantity of electricity, Mr. *Cavallo* connected one end of a chain with the string, and let the other end fall on the ground, and placed himself also on an insulating stool. Except the kite is raised in a thunder storm, there is no great danger that the operator will receive a shock. Although he raised his kite hundreds of times without any precaution whatever, he seldom received even a few slight shocks in the arms. But it is not adviseable to raise it while stormy clouds are over head. This is also less necessary, as the electricity of the atmosphere may then be easily observed by other means.

When the kite was raised, he often introduced the string through a window into a room of the house, and fastened it by a strong silk lace to a chair in the room. *Plate* N, IV *fig.* 78, A B represents part of the string of the kite, which comes within the room; C, the silk lace; D E, a small prime conductor, which by means of a small wire is connected with the string of the kite; F, a quadrant electrometer fixed upon an insulating stand, and placed near the prime conductor; G, a glass tube about eighteen inches long; g n, a ball and wire of brass, which are fixed to the glass tube. This small instrument is useful to determine the quality of the electricity, when it is not safe to come near the string. This is effected by touching the string with the wire, which takes a sufficient quantity from it to ascertain thereby the quality of the electricity, either by the attraction and repulsion of light balls, or the appearances of the electric light: or it may be ascertained by a Leyden jar, which will retain a charge for a considerable time; and then the kite need not be kept up any longer than is necessary to charge the jar, by which the quality will be shewn even at some days distance.

If a charged jar is carefully kept from any of those means by which it is known to be discharged, it will retain its charge for a long time. On this principle the above mentioned jar is constructed: the jar is coated in the usual manner; the uncoated part of the glass is covered with wax, or else well varnished; a glass tube, which is open at both ends, is cemented into the neck of this jar, having a piece of tin-foil connected with its lowest extremity, which touches the inside non-electric coating. A glass handle is fixed to the ball on the wire which passes into the foregoing glass tube; the wire is of a proper length to touch the tin-foil which is at the bottom of the tube. Charge this jar in the usual manner, and then take out the wire from the glass tube by means of the glass handle. This may be done without discharging the jar; and, as the fire cannot now escape easily, the charge of a jar may be preserved for many weeks.

Fig. 80 represents a very simple instrument, contrived by Mr. *Cavallo*, for making experiments on the electricity of the atmosphere, and which, on several accounts, appears to be the best for the purpose. A B is a common jointed fishing rod, without the last or smallest joint; from the extremity of this rod proceeds a small glass tube, C, covered with sealing-wax; a cork, D, is fixed at the end of it, from which an electrometer with pith balls is suspended. H G I, is a piece of twine fastened to the other extremity of the rod, and supported at G by a small string, F G. At the end of the twine, T, a pin is fastened, which, when pushed into the cork, D, renders the electrometer, E, uninsulated. When the electricity of the atmosphere is observed with this instrument, thrust the pin, T, into the cork, D, and hold the rod by the lower end, A; place it out of a window at the upper part of the house, raising the end of the rod with the electrometer, so as to make an angle of 50 or 60 degrees with the horizon. Keep the instrument in this situation for a few seconds, then pull the twine at H, and the pin will be disengaged from the cork, D; which operation causes the string to drop in the dotted situation, K L, and leaves the electrometer insulated, and electrified with an electricity contrary to that of the atmosphere. This being done, you may draw the electrometer into the room, and examine the quality of the electricity, without obstruction either from wind or darkness.

The aurora borealis seems not to affect the electricity of the kite.

The electrical spark taken from the string of the kite, or from any insulated conductor connected with it, especially when it does not rain, is seldom longer than a quarter of an inch, but it is exceedingly pungent. When the index of the electrometer is not higher than 20°, the person who takes the spark will feel the effects of it in his legs; it appears more like the discharge of an electric jar, than the spark taken from the prime conductor of an electrical machine.

The electricity of the kite is in general stronger or weaker, according as the string is longer or shorter; but it does not keep any exact proportion to it. For instance; the electricity brought down by a string of an hundred yards may raise the index of the electrometer to 20°, when, with double that length of string, the index of the electrometer will not go higher than 25°.

When the weather is damp, and the electricity is pretty strong, the index of the electrometer, after taking a spark from the string, or presenting the knob of a coated jar to it, rises surprizingly quick to its usual place; but, in dry or warm weather it rises exceedingly slow.

It appears, from the observations which have been made on the electricity of the atmosphere, that nature makes great use of this fluid for promoting vegetation.

1. In the spring, when plants begin to grow, then temporary electrical clouds begin to appear, and pour forth electric rain. The electricity of the clouds and of the rain continues to increase till that part of the autumn in which the last fruits are gathered.

2. It is this fluid which supplies common fire with that moisture, by the help of which it actuates and animates vegetation; it is the agent that collects the vapours, forms the clouds, and is then employed to disorder and dissipate them in rain.

3. From the same principle may be explained the proverb, that *No watering gives the country so smiling a look as rain.* The clouds of rain, by extending their electric atmosphere to the plants, dispose the pores of the latter to receive with greater facility the water which is impregnated with this penetrating and dilating fluid. Besides, it is natural to suppose, that the positive electricity, which continually prevails in serene weather, will contribute to promote vegetation, since this has been found to be the effect of even artificial electricity.

OF THE IMPERFECTIONS OF METEOROLOGY, SO LONG AS BAROMETRICAL, THERMOMETRICAL, AND HYGROMETRICAL OBSERVATIONS ARE NOT ACCOMPANIED WITH THE REGULAR OBSERVATION OF THE ELECTRICITY OF THE ATMOSPHERE, OF THE ELECTRICITY OF RAIN, SNOW, MISTS, AND AQUEOUS METEORS IN GENERAL. BY MR. ACHARD.

As it is now clearly ascertained, that electricity is a cause of various meteorological phenomena, it is rather surprizing that philosophers have not perceived the absolute necessity of joining an instrument, by which observations may be made on the electricity of the atmosphere, to those which indicate its weight, heat, and humidity.

Without considering in this place the different proofs of the influence of electricity on meteors, it will be sufficient to remark, that we cannot attain to an adequate knowledge of any phenomena, occasioned by the concurrence of various causes, without being acquainted with them all; for, if any one is neglected, it will be absolutely impossible thoroughly to explain the phenomena. If electricity is not the sole cause of several meteorological appearances, it is undoubtedly concerned more or less in their formation; so that, by neglecting to observe it, as well as the barometer, &c. we lose the fruits of other, even very exact, meteorological observations.

The influence of electricity on vegetation is proved by a set of observations made by different philosophers; but it evidently appears, that the botanical meteorological observations alone will never be so useful as might be expected, till we unite those made by an instrument which will indicate the electric state of the atmosphere, to those made with other instruments. It is owing to this cause, perhaps, that it is impossible to draw any conclusion from the botanical meteorological observations of Messrs. *Gautier* and *Duhamel*, which were continued from 1751 to 1769.

Mr. *Achard* has had an opportunity of making a few observations, but they were sufficient to convince him of the intimate connexion that subsists between the formation of the most part of meteors and atmospherical electricity.

To discover if the atmosphere was electrical, he made use of a pair of light pith balls, which were attached to a resinous rod. This electrometer, from its simplicity, is almost preferable to any other for merely discovering that electricity exists in the atmosphere.

During the month of July, 1778, Mr. *Achard* observed daily the electricity of the atmosphere in the morning, at noon, and in the evening, with a pair of small pith balls, which were placed above the roof of the house, above 40 feet high, and sufficiently distant from buildings, trees, &c. During the whole time there were only ten days which gave no signs of electricity; seventeen days, including the foregoing ten, in which he could observe no electricity in the morning, tho' it became very sensible at noon, and was very much increased towards the setting of the sun. Every other day he found the air electrical during the whole day, but always strongest a little before sun-set, a short time after which it began again to diminish.

If in serene weather the sky became suddenly cloudy, the electrometer indicated continual changes in the electricity of the atmosphere; sometimes increasing, then disappearing, then re-appearing; in which case it had generally changed from positive to negative, or *vice versa*. In windy weather, he found it difficult to observe with the electrometer, on account of the continual motion of the balls. It seemed to vary considerably when the air was heavy, but not windy. When the weather was very calm, and the sky without clouds, the electrometer did not alter in the least, except towards sun-set, when it increased in a small degree.

It is remarkable, that in those days in which he observed no electricity in the air, there was no dew at night; while, on the other nights, it fell in greater or less quantities. He does not think those observations are sufficient to determine, that the dew is occasioned by electricity; but it may, he thinks, be fairly inferred, that the elevation and fall of the dew is obstructed or promoted by the electricity of the air. It is easy to point out in what manner electricity may produce the effect. Let us suppose the air to be either positively or negatively electrified, but the surface of the globe where we are not to be so; the aqueous and volatile parts of the vegetables, exhaled by the rays of the sun, and suspended in the air, will become electric by communication. The air, cooling by the absence of the solar heat, will not, after the setting of the sun, retain the aqueous particles with the same force; and these being attracted by the non-electric bodies, which are on the surface of the earth, their superficies will be covered with dew. Again, let us suppose that the surface of the earth is electrical, but that the air is not electrical, and the effect will be similar to the preceding case. If the air and the earth are both electrified, but with contrary powers, the attraction will be stronger and the dew more abundant; but no dew will fall if they are both possessed of the same power, and in the same degree. It is known that the dew does dot fall with the same facility upon all bodies, and that electric bodies are those on which it falls with the greatest abundance.

This fact admits of an easy explanation, if we suppose electricity to be the cause of the dew; for the electric bodies do not readily receive electricity from the medium which surrounds them: there is, therefore, always a greater difference between the electricity of the air and that of the electrics which are placed in it, than between the electricity of the air and the conducting bodies which it envelopes. Now, it is in the ratio of this difference that the power of electric attraction acts, and consequently these bodies ought to be covered more abundantly with dew.

As electricity is often, if not always, the cause of dew, no one will doubt the nesessity of attending to it in the botanical meteorology, as every one is acquainted with the influence of dew on the growth of vegetables.

In the Phil. Trans. for 1773, are observations on the electricity of fogs, which prove that they are generally electrical. Mr. *Achard* has made several observations, the results of which correspond entirely with those, for he constantly found that the air was more or less electrified by a fog. Twice he observed, that in the space of a few minutes the fog ceased altogether, and fell in form of a fine rain; and, though it was very thick, disappeared in about seven minutes. It is also very probable that rain is occasioned by electricity; and of this we shall be convinced, if we consider the attractions and repulsions that the terrestrial or atmospheric electricity must occasion, as well between the surface of the globe and the vapours contained in the air, as between the particles of vapour which always necessarily tend to disperse or unite the aqueous particles which swim in the atmosphere, and to bring them nearer or carry them farther from the earth.

M. DE SAUSSURE'S OBSERVATIONS ON THE ATMOSPHERICAL ELECTRICITY.

The intensity of the atmospheric electricity is varied by a great many circumstances, some of which may be accounted for, others not. When the weather is not serene, it is impossible to assign any rule for their variation, as no regular correspondence can then be perceived with the different hours of the day, nor with the various modifications of the air. The reason is evident; when contrary and variable winds reign at different heights, when clouds are rolling over clouds, these winds and clouds, which we cannot perceive by any exterior sign, influence however the strata of air in which we make our experiments, produce these changes of which we only see the result, without being able to assign either the cause or its relation. Thus, in stormy weather, we see the electricity strong, then null, and in a moment after arise to its former force; one instant positive, the next negative, without being able to assign any reason for these changes. M. *De Saussure* says, that he has seen these changes succeed with such rapidity, that he had not time to note them down.

When rain falls without a storm, these changes are not so sudden; they are however very irregular, particularly with respect to the intensity of force; the quality thereof is more constant. Rain, or snow, almost uniformly gives positive electricity.

In cloudy weather, without rain or storms, the electricity follows generally the same laws as in serene weather.

Strong winds generally diminish its intensity; they mix together the different strata of the atmosphere, and make them pass successively towards the ground, and thus distribute the electricity uniformly between the earth and the air. M. *De Saussure* has observed a strong electricity with a strong north wind *(la bise.)*

The state of the air, in which the electricity is strongest, is foggy weather; this is always accompanied with electricity, except when the fog is going to resolve into rain.

The most interesting observations, and those which throw the greatest light upon the various modifications of electricity in our atmosphere, are those that are made in serene weather. In winter, during which most of M. *De Saussure*'s observations were made, and in serene weather, the electricity was generally weakest in the evening, when the dew had fallen, until the moment of the sun's rising; its intensity afterwards augmented by degrees, sometimes sooner and sometimes later; but generally before noon it attained a certain maximum, from whence it again declined, till the fall of the dew, when it would be sometimes stronger than it had been during the whole day; after which it would again gradually diminish during the whole night; but is never quite destroyed, if the weather is perfectly serene.

Atmospherical electricity seems therefore, like the sea, to be subject to a flux and re-flux, which causes it to increase and diminish twice in twenty-four hours. The moments of its greatest force are some hours after the rising and setting of the sun; those when it is weakest, precede the rising and setting thereof. This will be further explained in the following pages.

M. *De Saussure* has given an instance of this periodic flux in electricity, on the 22d of February, 1785, one of the coldest days ever remembered at Geneva: the hygrometer and thermometer were suspended in the open air, on a terrace exposed to the south-west; the electrometer, from its situation, indicated an electricity equal to what it would have shewn if it had been placed on an open plane. The height of the barometer is reduced to what it would have been if the mercury had been constantly at the temperature of ten degrees of *Reaumur*'s thermometer. The place of observation was elevated 60 feet above the level of the lake. The observations of the day preceding and following this great cold, are inserted in the following table; because it is pleasing to have the observations which precede and follow any singular phenomena. There was a weak S.W. wind during the whole three days; and it is rather remarkable, that most of the great colds, which have been observed at Geneva, were preceded by, or at least accompanied with, a little S. W. breeze.

A TABLE.

d.	h. m.		Barometer. feet in height.	Thermom.	Hygro.	Electro.	
21	9 15	M	26 6 7	— 8 3	89 3	2 0	Pale sun, cloudy
	11 10	M	26 6 5	— 4 3	83 9	1 6	Bright sun
	2 10	E	26 6 1	— 0 2	69 6	1 1	The same
	5	E	26 6 1	— 2 3	77 2	1 1	Setting sun
	6	E	26 6 0	— 5 2	85	1 0	Cloudy in the S. W.
	7	E	26 6 2	— 6 8	89	1 8	Perfectly clear
	8	E	26 6 3	—10 0	95	2 0	Idem
	9	E	26 6 3	—10 6	97 5	1 8	Idem
	10	E	26 6 1	— 9 9	95	1 2	Little cl. at horiz. S.
	11	E	26 6 0	—12 3	99 1	1 5	Id. more to S. W.
	12	E	26 5 15	—12 5	hoar frost	1 2	Idem
22	1	M	26 6 0	—14 3	Idem	0 9	Idem
	2	M	26 6 8	—14 5	Id.	1 2	Clo. incr. & appro.
	6 15	M	26 5 7	—15 0	Id.	0 8	Clear
	7 30	M	26 5 4	—14 7	Id.	1 2	Light fog
	8 10	M	26 5 2	—14 2	Id.	1 1	Idem
	9 10	M	26 4 15	—10 7	Id.	1 6	Idem
	10 10	M	26 4 13	— 8 2	Id.	2 2	Thicker fog
	11 10	M	26 4 3	— 4 8	Id.	1 8	Idem
	1 10	E	26 4 0	— 4 9	Id.	1 7	Idem
	2 20	E	26 3 14	+ 0 6	82	1 4	Weak fog, pale sun
	3 30	E	26 3 13	— 0 9	81 9	1 1	Cloudy pale sun
	5	E	26 3 13	— 4 3	89	1 2	Less cloudy
	6	E	26 3 14	— 4 4	91 2	2 2	More so
	7	E	26 3 14	— 6 1	94	1 7	Idem
	8	E	26 3 13	— 5 9	Id.	3 7	Clou. fog in S. W.
23	0 45	M		— 4 1	Id.	1 0	Clou. with more fog
	8 5	M	26 5 0	— 1 0	81 3	1 2	Idem
	10 7	M	26 5 5	— 0 0	76	0 8	Idem
	3 45	E	26 6 8	+ 0 5	76	Id.	Cloudy pale sun
	5	E	26 6 14	— 0 3	75 3	1 0	Cloudy
	6	E	26 7 3	— 0 7	74	0 8	Idem
	7	E	26 7 9	— 1 7	79 7	2 2	Very clear
	8	E	26 7 14	— 3 7	87 3	1 7	Cloudy
	12	E	26 9 1	— 3 0	92	0 5	More so

M for Morning, E for Evening.

From the first eighteen observations of this table, when the sky was quite serene, we see that the electricity was pretty strong at nine in the morning, that from thence it gradually diminished till towards six in the evening, which was its first minimum; after which it increased again till eight, its second maximum; from whence it again gradually declined till six the next morning, which was the time of its second minimum; after which it again increased till ten in the morning, which was the first maximum of the following day; as this was cloudy, the electric periods were not so regular.

The electricity of serene weather is much weaker in summer than in winter, which renders it more difficult to observe these gradations in summer than in winter; besides a variety of accidental causes, which at the same time render them more uncertain. In general, in summer, if the ground has been dry for some days, and the air is dry also, the electricity increases from the rising of the sun till three or four in the afternoon, when it is strongest; it then diminishes till the dew begins to fall, which again reanimates it; though after this it declines, and is almost extinguished during the night.

But the serene days that succeed rainy weather in summer, generally exhibit the same diurnal periods or states of electricity, as are to be observed in winter.

The air is invariably positive in serene weather, both in winter and summer, day and night, in the sun or in the dew. It would seem, therefore, that the electricity of the air is essentially positive, and that, whenever it appears to be negative, in certain rains or in storms, it probably arises from some clouds, which have been exposed to the pressure of the electric fluid contained in the upper part of the atmosphere, or to more elevated clouds, that have discharged a part of their fluid upon the earth or upon other clouds.

In order to find out the cause of these phenomena, M. *De Saussure* instituted a set of experiments on evaporation, avoiding the use of Mr. *Volta*'s condenser.

To produce a strong evaporation, he threw a mass of red-hot iron into a small quantity of water which was contained in a coffee pot with a large mouth, and suspended by silken strings; by this he obtained a strong positive electricity, though, according to Mr. *Volta*'s system, it ought to have been negative; the experiment was repeated several times, varying in some of the circumstances, but the result was always the same.

As it was not easy to think so able a philosopher as Mr. *Volta* was deceived, it was necessary to try the experiment in a manner more analogous to that of Mr. *Volta*. A small chafing-dish was, therefore, insulated by silken cords, and the coffee-pot, with a small quantity of water, placed on it; one electrometer was connected with the coffee-pot, and another with the chafing-dish; the fire was raised by a pair of bellows. When the water had boiled strongly for a few minutes, both electrometers exhibited signs of electricity, which, on examination, was found to be negative; proving the truth of Mr. *Volta*'s experiment. The evaporation produced by the effervescence of iron in the vitriolic acid, and by that of chalk in the same acid, gave also negative electricity.

It was now necessary to inquire, why the vapour excited by the heated iron produced positive electricity, while that from boiling water, in any other way, produced a negative electricity.

M. *De Saussure* suspected, that the intensity of heat to which the water is exposed, by the contact of a body in the state of incandescence, was the cause of the electricity produced by its evaporation, and that a combination was then formed, by which a new quantity of the electric fluid was produced. This conjecture may at first sight seem improbable; but, the quantity of electricity produced by this experiment will astonish those that repeat it: and this quantity is the more surprizing, because, if it is true, according to the system of Mr. *Volta*, that vapours absorb, while they are forming, a quantity of the electric fluid, there must therefore be enough developed in this experiment for the formation of the great quantity of vapours produced by the heated iron, and afterwards a sufficient quantity to electrify strongly the apparatus and all these vapours.

This experiment shews clearly the cause of that prodigious quantity of electricity, which is unfolded in the eruption of volcanos; as it is probable that the water in these, from many circumstances, acquires a much greater degree of heat than is given to it in our experiments.

To verify this conjecture, that it was in some measure the combustion of the water, or the iron, that produced the positive electricity, it was proper to try whether, by a regular moderation of the heat of the iron, positive electricity would always be obtained. This was essayed in the following manner: a large iron crucible, five inches high, four in diameter, and six lines thick, was heated red-hot, then insulated; after which small quantities of water were thrown into it, each projection of the water cooling more and more the crucible; thus descending by degrees, till there was only sufficient heat to boil the water, carefully observing and then destroying the electricity produced at each projection. The electricity was always positive, or null: at the first projections it was very strong; it gradually diminished to the twelfth, when it was scarce sensible, though always with a tendency to be positive.

On repeating this experiment, and varying it in different ways, a remarkable circumstance was observed: when a small quantity of water was thrown into the crucible, the moment it was taken from the fire, while it was of a pale red, approaching what is called the white heat, no electricity was obtained.

This fact seemed to have some connexion with another, mentioned by M*usschembroeck*, that water evaporates more slowly on metal, or any other incandescent body, than on the same body heated only a small degree above boiling water. To examine this relation, and to find whether there was any between the periods of evaporation and the production of electricity, M. *De Saussure* made a great number of experiments, which are most accurately described in his excellent work; but, as the detail would be much too long to be introduced in this work, I must content myself with presenting the reader with the heads thereof, and a description of the apparatus.

The apparatus consisted of a pot of clay, well baked or annealed, fifteen lines thick, and four inches diameter; this was insulated by a dry glass goblet: upon this pot was placed the crucible, or any other heated substance, upon which the water was to be thrown in order to be reduced into vapours; the crucible was contiguous to a wire connected with an electrometer; a measure containing 54 grains weight of distilled water was thrown upon the heated crucible; the time employed in the evaporation thereof was observed by a second watch; the electricity produced by this evaporation was noted. When this measure of water was reduced into vapour, the electricity of the apparatus is destroyed, and a fresh measure of water is thrown into the crucible; proceeding in the same manner till the crucible is almost cold.

The first experiment was with an iron crucible, from which it was found, that *Musschembroeck* was not right in saying, that the evaporation was slowest when the iron was hottest; for, at the instant it was taken from the fire, it required nineteen seconds to evaporate the water, and took more time till the third projection, when it took thirty-five seconds; though from that period it employed less time, or, in other words, the evaporation accelerated in proportion as the iron cooled.

With respect to the electricity, it was at first 0, then positive, afterwards negative, then 0, and afterwards positive to the end of the experiment. The vapour was not visible till the seventh projection.

In the second experiment with the same crucible, though every endeavour was made use of to render them as similar as possible, the electricity was constantly positive.

The third experiment was with a copper crucible; here also the electricity was positive, and the longest time employed in evaporation was not the instant of the greatest heat. It was very curious to see the water endeavouring to gather itself into a globule, like mercury on glass; to be sometimes immoveable, and then to turn on itself horizontally with great rapidity; sometimes throwing from some of its points a little jet, accompanied with an hissing noise.

The fourth experiment was with the same crucible; the electricity was at first negative, then constantly positive.

The fifth was with a crucible of pure silver; a considerable time was employed here in evaporating the same quantity of water, even in the instant of the greatest heat it took five minutes six seconds; the electricity was weak, three times no electricity was perceived, five times negative electricity was discovered.

In a sixth experiment with the same crucible, a positive electricity was obtained, at the second projection; after which none of any kind was perceived.

The seventh, with the same, gave at first a strong negative electricity; the second and third projection gave a weak positive electricity.

The eighth was made with a porcelain cup; here the evaporation was slower at the second, than the first projection; but, from this it took longer time till it was cold, contrary to what happened with the metals: the electricity was always negative.

The ninth and tenth experiments, with the same cup, produced similar effects.

The eleventh experiment was with spirit of wine in a silver crucible; here there was no electricity produced at the two first projections, and what was afterwards obtained was negative.

The twelfth experiment, with ether; here the electricity was also negative. These two inflammable fluids, in evaporating, followed the same laws as water, being dissipated at first most rapidly in the greatest heat; afterwards taking a longer and longer time before they were evaporated, to a certain period; then employing less time, or evaporating quicker, till the crucible was nearly cold.

Now, as china and silver always produced negative electricity, while iron and copper have generally given positive electricity, we may conclude that electricity is positive with those bodies that are capable of decomposing water, or of being decomposed themselves by their contact with the water; and negative with those which are not at all decomposed or altered.

From hence M. *De Saussure* conjectures, that the electric fluid may be looked upon as formed by the union of fire with some unknown principle, perhaps a fluid analogous to inflammable air, but exceedingly more subtile. This analogy seems to him sufficiently proved by the inflammation of the electric fluid, and by the diminution of the air in which this inflammation is made. Though many doubts have been attempted to be thrown on this inflammation, there seems to be one reason which forces us to admit it, which is, the loss of a quantity of this fluid at every spark; we may diminish at pleasure any quantity of this fluid *(en le faisant etinceler)* by taking a number of sparks from it. From whence also it may be inferred, that a considerable quantity is destroyed every day by thunder.

According to this system, when the operation, which converts water into vapour, produces at the same time a decomposition, it then generates the electric fluid. A part of this fluid combines itself immediately with these vapours, and serves even to form them. The vessel in which this operation is performed will acquire a positive electricity, none at all, or a negative; according as the quantity of the fluid generated is superior, equal, or inferior to that which the formation of the vapours consumes. When no decomposition accompanies the evaporation, the electricity ought to be constantly negative, because there is nothing to replace the quantity of this fluid which is employed in forming the vapour.

If, in the foregoing experiments, those substances which were susceptible of calcination had constantly given a positive electricity, and those which do not calcine had always given the negative, every thing would have been explained by these principles, and they would thence have acquired a greater degree of probability. But the phenomena have not always followed this law; we have seen iron and copper sometimes give a negative electricity, and silver the positive. The first case is not difficult to account for; it is well known with what facility iron and copper calcine in a brisk fire; they become covered with a scaly crust, which is not susceptible of any further alteration with the same heat. If the bottom of the crucible acquires this crusty coating, the drop of water placed thereon will be no longer in contact with a calcinable substance; there will be no further decomposition, no generation of the electric fluid: the vapours, however, which are still formed will absorb a part of the fluid naturally contained in the apparatus, and this will therefore be electrified negatively. If some of the scales should be so far detached, that the water may gain some points of contact, the quantity thus generated may compensate for what is absorbed by the vapours, and thus the electricity will be null: if more are detached, it will super-abound and be positive. From the same reasons, a large mass of water, by attacking the iron in a greater number of points, always gives positive electricity; and hence also a strong positive electricity is obtained, by throwing a piece of red-hot iron into a mass of water.

It is not so easy to explain, why silver gives sometimes a positive electricity, but by supposing it to have been mixed with some substances capable of calcination; and this the more, as the white porcelain always gave negative electricity. This supposition was verified by some subsequent experiments, in which the same silver, when purified, always gave a negative electricity.

M. *De Saussure* owns himself incapable of explaining, why heated charcoal always gives negative electricity; unless it can be attributed to the promptitude with which so rare a substance loses its heat by the contact of water.

One fact astonished him, namely, that by combustion, properly so called, although it is an evaporation, nay, the highest degree of evaporation, he never obtained any signs of electricity; though he tried to obtain it in a variety of ways. Probably the current produced by the flame disperses and dissipates the electricity as soon as it is formed. The case, however, must not be looked upon as general, because Mr. *Volta* obtained signs of electricity from bodies in combustion by means of his condenser.

Another singular fact was, his not being able to obtain electricity without ebullition, though he endeavoured to compensate by the quantity of surface for the quantity of vapours that was elevated by boiling water; and, indeed, the same quantity of water, if extended over too large a surface, will not give any electricity.

Notwithstanding the uncertainty these experiments throw upon the system, it does not at present seem possible to find another reason, which so satisfactorily accounts for the positive electricity which reigns in the air. The prodigious quantity of this fluid, which continually descends from the upper part of the atmosphere, filtrating through the air to penetrate the interior parts of the earth, must necessarily be brought back again by some means; for, otherwise, the air would be exhausted of its fluid, or the earth would be saturated. The perpetual circulation of this fluid, which is carried on by means of vapours, is a striking circumstance; it rises invisible and inactive, concealed in their bosom, but displaying afterwards its energy. When the vapours have changed their form, it descends active, animated with a penetrating and expansive force; tops of trees, the points of leaves, the beards of different grains, attract and force it to pass through the vegetables, of which it becomes, perhaps, when decomposed, the most active and savoury part. This also may be one of the reasons, why exercise in the open air is much more conducive to health than that which is taken in covered or close places; for it seems evident, that the soft and gentle electrization, which every one must partake of in the open air, must have an influence upon our organs, on the circulation of the blood, the secretion of the humours, and insensible transpiration.

In further pursuing this subject, we must consider, that vapour sometimes acts as the producing cause of aerial electricity; at other times, as a conductor of this same fluid; and sometimes, both together. Towards the end of the night the electricity of the air is very weak, either because there is no evaporation, or because the humidity of the preceding evening and that of the fore part of the night have transmitted to the earth the electricity that was accumulated in the air: but, as soon as the sun warms the earth, and in proportion as he rises above the horizon, the aerial electricity augments; because the vapours which then rise carry this fluid into the air. But, when the sun has attained the meridian, the heat increases in a greater proportion than the evaporation, the air becomes dry, and hardly transmits the fluid which is accumulated in the upper part of the atmosphere; the electrometer, therefore, exhibits less signs of electricity, though it is still accumulating in the upper part of the atmosphere. Lastly, when the sun is near setting, the air grows cool, becomes humid, and transmits more abundantly to the earth the electric fluid that was accumulated in the higher regions; the electrometer, therefore, rises again with the dew, till two or three hours after sun-set, when the air is exhausted, and the electricity again diminishes till the next day.

In summer, the electricity of a serene atmosphere is much weaker than in winter, and that because the air is then warm and dry to a greater height, and therefore resists more powerfully the transmission of this fluid, that is accumulated in the higher regions of the atmosphere. This interrupted accumulation accounts at the same time very naturally for the violence and frequency of storms at this season. But the increase of electricity, from the heat of the sun in the dry and hot days of summer, from its rising till four or five in the afternoon, is not so easily accounted for. It is not improbable, that the dry exhalations from the earth, which are occasioned by the heat, may produce this augmentation of electricity, and favour the descent thereof from the upper part of the atmosphere. It appears however in general, both in winter and summer, that when the air is perfectly transparent, the aerial electricity always diminishes in the hottest part of the day. It is known, that the air is generally most transparent and disengaged from vapours in the serene weather that follows great or heavy rains. M. *De Saussure* desires that this system may be only looked upon as so many conjectures, proposed with a view to animate other philosophers to the observation of these phenomena, and the investigation of their cause.

The author refers also to his "Essais sur l'Hygrometrie" for the proofs, That the electric fluid is only necessary to form or suspend the gross vesicular vapours. Those which are dissolved, or are elastic, support themselves by the expansive force which they acquire from the element of fire combined with them, without the assistance of any other agent. And these gross vapours, which require the electric fluid for their formation, part with it, if they are resolved into water or into an elastic fluid. Thus the gross vapours that are formed in the morning of a fine day, and which disturb a little the transparency of the inferior strata of air, carry this fluid with them, but part with it when they come into a more pure and dry air, where they are dissolved, taking the form of an elastic fluid.

This explains the diminution of the aerial electricity, where clouds are forming in an atmosphere that was serene; for the electric fluid, which was disseminated in the air, combines with the vapours when they take the vesicular form; the strata or striated appearance that is then seen among the clouds, which is one of the most sure indications of rain, seems to pronounce the presence of the electric fluid, endeavouring to restore an equilibrium, and replace that which has been employed in the formation of the vesicles of which the clouds consist. Many experiments shew, that this fluid, condensed by art, disposes in parallel and converging lines, like the clouds, those particles of dust through which it is made to pass; while, on the other hand, the increase of aerial electricity, which is observed when the air is getting clear and serene after rain, arises from this fluid, which the vesicular vapours part with when dissolved in air.

OBSERVATIONS AND EXPERIMENTS MADE BY DR. PRIESTLEY, ON THE EFFECTS OF ELECTRICITY ON DIFFERENT ELASTIC FLUIDS.

EXPERIMENT CCXXXIX. *To change the blue colour of liquors tinged with vegetable juices red.* The apparatus for this purpose is seen in *fig.* 94.

A B is a glass tube, about four or five inches long and one or two tenths of an inch diameter in the inside; a piece of wire is put into one end of the tube, and fixed there with cement; a brass ball is placed on the top of this wire; the lower part of the tube from *a* is to be filled with water tinged blue with a piece of turnsole or archal. This is easily effected, by setting the tube in a vessel of the tinged water, then placing it under a receiver on the plate of the air-pump; exhaust the receiver in part, and then, on letting in the air, the tinged liquor will rise in the tube, and the elevation will be in proportion to the accuracy of the vacuum; now take the tube and vessel from under the receiver, and throw strong sparks on the brass ball from the prime conductor.

When Dr. *Priestley* made this experiment, he perceived, that after the electric spark had been taken, between the wire, *b*, and the liquor at *a*, about a minute, the upper part of it began to look red; in two minutes it was manifestly so, and the red part did not readily mix with the liquor. If the tube was inclined when the sparks were taken, the redness extended twice as far on the lower side as on the upper. In proportion as the liquor became red, it advanced nearer to the wire, so that the air in which the sparks were taken was diminished; the diameter amounted to about one-fifth of the whole space; after which, a continuance of the electrification produced no sensible effect.

To determine, whether the cause of the change of colour was in the air, or in the electric matter, Dr. *Priestley* expanded the air in the tube, by means of an air-pump, till it expelled all the liquor, and admitted fresh blue liquor in its place; but, after this, electricity produced no sensible effect on the air or on the liquor: so that it was clear, that the electric matter had decomposed the air, and made it deposit something of an acid nature. The result was the same with wires of different metals. It was also the same when, by means of a bent tube, the spark was made to pass from the liquor in one leg, to the liquor in the other. The air thus diminished was in the highest degree noxious.

In passing the electric spark through different elastic fluids, it appears of different colours: in fixed air, the spark is very white; in inflammable and alkaline air, it appears of a purple or red colour. From hence we may infer, that the conducting power of these airs is different, and that fixed air is a more perfect non-conductor than inflammable air.

The spark was not visible in air from a caustic alkali, made by Mr. *Lane,* nor in air from spirit of salt; so that they seem to be more perfect conductors of electricity than water, or other fluid substances.

The electric spark, taken in any kind of oil, produces inflammable air. Dr. *Priestley* tried it with ether, oil of olives, oil of turpentine, and essential oil of mint, taking the electric spark in them without any air to begin with; inflammable air was produced in them all.

Dr. *Priestley* found, that on taking a small electric explosion for an hour in the space of an inch of fixed air, confined in a glass tube one-tenth of an inch diameter, when water was admitted to it, only one-fourth of the air was imbibed. Probably the whole would have been rendered immiscible in water, if the electrical operation had been continued a sufficient time.

The electric spark, when taken in alkaline air, appears of a red colour; the electric explosions, which pass through this air, increase its bulk; so that, by making about 200 explosions in a quantity of it, the original quantity will be sometimes increased one-fourth. If water is admitted to this air, it will absorb the original quantity, and leave about as much elastic fluid as was generated by the electricity, and this elastic fluid is a strong inflammable air.

Dr. *Priestley* found, when the electric spark was taken in vitriolic acid air, that the inside of the tube in which it was confined was covered with a blackish substance. He seems to think, that the whole of the vitriolic acid air is convertible into this black matter, not by means of any union which it forms with the electric fluid, but in consequence of the concussion given to it by the explosion; and that, if it be the calx of the metal which supplied the phlogiston, it is not to be distinguished from what metal, or indeed from what substance of any kind, the air had been extracted.

Dr. *Priestley* made 150 explosions of a common jar in about a quarter of an ounce measure of vitriolic acid air from copper; by which the bulk was diminished about one-third, and the remainder seemingly not changed, being all absorbed by water. In the course of this process, the air was carefully transferred three times from one vessel to another; and the last vessel, in which the explosions were made, was to all appearance as black as the first; so that the air seems to be all convertible into this black substance.

Thinking this diminution of the vitriolic acid air might arise from its absorption by the cement, with which the glass tubes employed in the last experiment were closed, he repeated it with the air from quicksilver in a glass syphon confined by quicksilver, and the result was the same.

That this matter comes from the vitriolic acid air only, and not from any combination of the electric matter with it, will appear from the following experiment.

He took the simple electric spark from a conductor of a moderate size, for the space of five minutes without interruption, in a quantity of vitriolic acid air, without producing any change in the inside of the glass; when, immediately after, making in it only two explosions of a common jar, each of which might be produced in less than a quarter of a minute with the same machine in the same state, the whole of the inside of the tube was completely covered with the black matter. Now, had the electric matter formed any union with the air, and this black matter had been the result of that combination, all the difference that would have risen from the simple spark, or the explosion, could only have been a more gradual or a more sudden formation of that matter.

A large phial, about an inch and an half wide, being filled with this air, the explosion of a very large jar, containing more than two feet of coated surface, had no effect upon it; from which it should seem, that in these cases the force of the shock was not able to give the quantity of air such a concussion as was necessary to decompose any part of it.

He had generally made use of copper, but afterwards he procured this air from almost every substance from which it could be obtained; the electric explosion taken in it produced the same effect. But, as some of the experiments were attended with peculiar circumstances, he briefly mentions them as follows.

When he endeavoured to get vitriolic acid air from lead, putting a quantity of leaden shot into a phial containing oil of vitriol, and applying only the usual degree of heat, a considerable quantity of heat was produced; but afterwards, though the heat was increased till the acid boiled, no more air could be got. He imagined therefore, that in this case the phlogiston had, in fact, been supplied by something that had adhered to the shot. However, in the air so produced, he took the electric explosion; and, in the first quantity he tried, a whitish matter was produced, almost covering the inside of the tube; but, in the succeeding experiments, with air produced from the same shot, or something adhering to it, there was less of the whitish matter; and at last, nothing but black matter was produced, as in all the other experiments. Water being admitted to this air, there remained a considerable residuum, which was very slightly inflammable.

Vitriolic acid air is easily procured from spirit of wine, the mixture becoming black before any air is yielded. The electric explosion taken in this air also produced the black matter.

The experiments made with ether seem to throw most light upon this subject, as this air is as easily procured from ether as any other substance containing phlogiston. In the air procured by ether, the electric explosion tinged the glass very black, more so than in any other experiment of the kind; and, when water had absorbed what it could of this air, there was a residuum in which a candle burned with a lambent blue flame. But what was most remarkable in this experiment was, that besides the oil of vitriol becoming very black during the process, a black substance and of a thick consistence was formed, which swam on the surface of the acid.

It is very possible, that the analysis of this substance may be a means of throwing light upon the nature of the black matter formed by electric explosions in vitriolic acid air, as they seem to resemble one another very much.

The electric spark or explosion taken in common air, confined by quicksilver in a glass tube, covers the inside of the tube with a black matter, which, when heated, appears to be pure quicksilver. This, therefore, may be the case with the black matter into which he supposed the vitriolic acid air to be converted by the same process, though the effect was much more remarkable than in the common air. The explosion will often produce the diminution of common air in half the time that simple sparks will do it, the machine giving the same quantity of fire in the same time: also the blackness of the tube is much sooner produced by the shocks than by the sparks. When the tube considerably exceeds three-tenths of an inch in diameter, it will sometimes become very black, without there being any sensible diminution of the quantity of air.

EXPERIMENTS ON AIR, BY HENRY CAVENDISH, ESQ.

The apparatus used in making the experiments was as follows. The air, through which the spark was intended to be passed, was confined in a glass tube bent to an angle, *plate* 1, *fig*. 23, which, after being filled with quicksilver, was inverted into two glasses of the same fluid; the air to be tried was then introduced by means of a small tube, such as is used for thermometers, bent in the manner represented by A B C, *fig*. 16; the bent end of which, after being previously filled with quicksilver, was introduced, as in the figure, under the glass D E F, inverted into water, and filled with the proper kind of air, the end, C, of the tube being kept stopped by the finger; then, on removing the finger from C, the quicksilver in the tube descended in the leg B C, and its place was supplied with air from the glass, D E F. Having thus got the proper quantity of air into the tube, A B C, it was held with the end, C, uppermost, and stopped with the finger; and the end, A, made smaller for that purpose, being introduced into one end of the fore-mentioned bent tube, the air, on removing the finger from C, was forced into that tube by the pressure of the quicksilver in the leg, B C. By these means he was enabled to introduce the exact quantity he pleased of any kind of air into the tube, M, *fig.* 23; and by the same means, could let up any quantity of soap-lees, or any other liquor, which he wanted to be in contact with the air.

In one case, however, in which he wanted to introduce air into the tube many times in the same experiment, he used the apparatus represented in *plate* 1, *fig.* 17, consisting of a tube, A B, of small bore; a ball, C; and a tube, D E, of a larger bore. This apparatus was first filled with quicksilver, and then the ball, C, and the tube, A B, were filled with air, by introducing the end, A, under a glass inverted into water, which contained the proper kind of air, and drawing out the quicksilver from the leg, E D, by a syphon. After being thus furnished with air, the apparatus was weighed, and the end, A, introduced into one end of the tube, M, and kept there during the experiment; the way of forcing air out of this apparatus into the tube, being by thrusting down the tube, E D, a wooden cylinder, of such a size as almost to fill up the whole bore, and by occasionally pouring quicksilver into the same tube, to supply the place of that pushed into the ball, C. After the experiment was finished, the apparatus was weighed again, which shewed exactly how much air had been forced into the tube, M, during the whole experiment, it being equal in bulk to a quantity of quicksilver whose weight was equal to the increase of weight of the apparatus.

The bore of the tube, M, *fig.* 23, used in most of the following experiments, was about one-tenth of an inch; and the length of the column of air, occupying the upper part of the tube, was in general from one inch and an half to three quarters of an inch.

It is scarcely necessary to inform any one used to electrical experiments, that, in order to force an electrical spark through the tube, it was necessary, not to make a communication between the tube and the conductor, but to place an insulated ba at such a distance from the conductor as to receive a spark from it, and to make a communication between that ball and the quicksilver in one of the glasses, while the quicksilver in the other glass communicated with the ground.

When the electric spark was made to pass through common air, included between short columns of a solution of litmus, the solution acquired a red colour, and the air was diminished conformably to what was discovered by Dr. *Priestley*. When lime-water was used instead of the solution of litmus, and the spark was continued till the air could be no further diminished, not the least cloud could be perceived in the lime-water; but the air was reduced to two-thirds of its original bulk, which is a greater diminution than it could have suffered by mere phlogistication, as that is very little more than one-fifth of the whole.

The experiment was next repeated with some impure dephlogisticated air. The air was very much diminished, but without the least cloud being produced in the lime-water; neither was any cloud produced when fixed air was let up to it; but, on the further addition of a little caustic volatile alkali, a brown sediment was immediately perceived.

Hence we may conclude, that the lime-water was saturated by some acid formed during the operation; as in this case it is evident, that no earth could be precipitated by the fixed air alone, but that caustic volatile alkali, on being added, would absorb the fixed air, and thus becoming mild, would immediately precipitate the earth; whereas, if the earth in the lime-water had not been saturated with an acid, it would have been precipitated by the fixed air. As to the brown colour of the sediment, it most likely proceeded from some of the quicksilver having been dissolved.

It must be observed, that if any fixed air, as well as acid had been generated in these two experiments with the lime-water, a cloud must have been at first perceived in it, though that cloud would afterwards disappear, by the earth being re-dissolved by the acid; for, till the acid produced was sufficient to dissolve the whole of the earth, some of the remainder would be precipitated by the fixed air; so that we may safely conclude, that no fixed air was generated in the operation.

When the air is confined by soap-lees, the diminution proceeds rather faster than when it is confined by lime-water; for which reason, as well as on account of their containing so much more alkaline matter in proportion to their bulk, soap-lees seemed better adapted for experiments designed to investigate the nature of this acid, than lime-water. Accordingly some experiments were made, to determine what degree of purity the air should be of, in order to be diminished most readily and to the greatest degree; and it was found, that when good dephlogisticated air was used, the diminution was but small; when perfectly phlogisticated air was used, no sensible diminution took place; but, when five parts of pure dephlogisticated air were mixed with three parts of common air, almost the whole of the air was made to disappear. It must be considered, that common air consists of one part of dephlogisticated air mixed with four of phlogisticated; so that a mixture of five parts of pure dephlogisticated air and three of common air, is the same thing as a mixture of seven parts of dephlogisticated air with three of phlogisticated.

Having made these previous trials, introduce into the tube a little soap-lees, and then let up some dephlogisticated and common air, mixed in the above-mentioned proportions, which rising to the top of the tube, M, divided the soap-lees into its two legs, as fast as the air was diminished by the electric spark; continue adding more of the same kind, till no further diminution takes place: after which, a little pure dephlogisticated air, and after that a little common air, were added, in order to see whether the cessation of diminution was not owing to some imperfection in the proportion of the two kinds of air to each other; but without effect. The soap-lees being then poured out of the tube, and separated from the quicksilver, seemed to be perfectly naturalized, as they did not at all discolour paper tinged with the juice of blue flowers. Being evaporated to dryness, they left a small quantity of salt, which was evidently nitre, as appeared by the manner in which paper impregnated with a solution of it burned.

For more satisfaction, he tried this experiment over again, on a larger scale. About five times the former quantity of soap-lees were now let up into a tube of a larger bore; and a mixture of dephlogisticated and common air, in the same proportions as before, being introduced by the apparatus represented in *fig.* 9, the spark was continued till no more air could be made to disappear. The liquor, when poured out of the tube, smelled evidently of phlogisticated nitrous acid. This salt was found, by the manner in which paper dipped into a solution of it burned, to be true nitre. It appeared by the test of terra ponderosa salita, to contain not more vitriolic acid than the soap-lees themselves contained, which was excessively little; and there is no reason to think that any other acid entered into it, except the nitrous.

A circumstance however occurred, which at first seemed to shew that this salt contained some marine acid; namely, an evident precipitation took place, when a solution of silver was added to some of it dissolved in water; though the soap-lees used in its formation were perfectly free from marine acid, and though, to prevent all danger of any precipitate being formed by an excess of alkali in it, some purified nitrous acid had been added to it, previous to the addition of the solution of silver. On consideration, however, he suspected, that this precipitation might arise from the nitrous acid in it being phlogisticated; and therefore tried, whether nitre much phlogisticated would precipitate silver from its solution. For this purpose, he exposed some nitre to the fire in an earthen retort, till it had yielded a good deal of dephlogisticated air; and then, having dissolved it in water, and added to it some well purified spirit of nitre, till it was sensibly acid, in order to be certain that the alkali did not predominate, he dropped into it some solution of silver, which immediately made a very copious precipitate. This solution, however, being deprived of some of its phlogiston by evaporation to dryness, and exposure for a few weeks to the air, lost the property of precipitating silver from its solution; a proof that this property depended only on its phlogistication, and not on its having absorbed sea salt from the retort, or by any other means.

Hence it is certain that nitre, when much phlogisticated, is capable of making a precipitate with a solution of silver; and, therefore, there is no reason to think that the precipitate, which our salt occasioned with a solution of silver, proceeded from any other cause than that of its being phlogisticated; especially as it appeared by the smell, both on first taking it out of the tube, and on the addition of the spirit of nitre previous to dropping in the solution of silver, that the acid in it was much phlogisticated. The property of phlogisticated nitre is worth the attention of chemists; as otherwise they may sometimes be led into mistakes, in investigating the presence of marine acid by a solution of silver.

In a former paper Mr. *Cavendish* has asserted, that when nitre is detonated with charcoal, the acid is converted into phlogisticated air; that is, into a substance which, as far as he could perceive, possesses all the properties of the phlogisticated air of our atmosphere: from which he concluded, that phlogisticated air is nothing else than nitrous acid united to phlogiston. According to this conclusion, phlogisticated air ought to be reduced to nitrous acid, by being deprived of its phlogiston; but, as dephlogisticated air is only water deprived of phlogiston, it is plain, that adding dephlogisticated air to a body is equivalent to depriving it of phlogiston and adding water to it; and therefore phlogisticated air ought also to be reduced to nitrous acid, by being made to unite to, or form a chemical combination with, dephlogisticated air; only, the acid formed this way will be more dilute than if the phlogisticated air was simply deprived of phlogiston.

This being premised, we may safely conclude, that in the present experiments the phlogisticated air was enabled, by means of the electrical spark, to unite to, or form a chemical combination with, the dephlogisticated air, and was thereby reduced to nitrous acid, which united to the soap-lees and formed a solution of nitre; for in these experiments those two airs actually disappeared, and nitrous acid was actually formed in their room: and as, moreover, it has been just shewn, from other circumstances, that phlogisticated air must form nitrous acid when combined with dephlogisticated air, the above-mentioned opinion seems to be sufficiently established. A further confirmation of it is, that, as far as we can perceive, no diminution of air is produced when the electric spark is passed either through pure dephlogisticated air or through perfectly phlogisticated air; which indicates the necessity of a combination of these two airs to produce the acid. Moreover, it was found in the last experiment, that the quantity of nitre procured was the same that the soap-lees would have produced if saturated with nitrous acid; which shews that the production of the nitre was not owing to any decomposition of the soap-lees.

BENNET ON ATMOSPHERIC ELECTRICITY.

To illustrate the process of atmospheric explosions, as far as relates to the influence of powerful electrical atmospheres:

Let two slips of gold leaf, or rather white Dutch metal, be fastened to a brass ball suspended by a silken string, or other insulating substance; bring the brass knob of a charged jar towards the points of the metallic slips, till they become charged with electricity, which will cause them to be repelled each way from the knob of the jar, and stand as in *plate* 1, *fig*. 21. Continue to hold the jar in the same position during a few seconds, and one of the slips will bend towards the knob of the jar, *fig*. 21, and strike it suddenly; then it will stand repelled till its electricity be again dissipated: in this manner it will continue to repeat the stroke as long as a sufficient quantity of electricity remains in the jar, unless the air be very dry, and then this experiment may fail, which with me has only happened twice.

The most common apparatus hitherto used, has chiefly consisted of high, pointed, and insulated conducting rods or wires, extending from the place of observation to the top of an high building or steeple, and connected with an electrometer;

or, the small and insensible communications of electricity have been collected by means of Mr. *Volta*'s condenser. But these instruments are generally either not sufficiently sensible, or they can only shew the state of atmospheric electricity at intervals; whence the observer loses the opportunity of watching the momentary and interesting change which happens in several states of the atmosphere, especially during the passage of a thunder cloud.

It has been found, that the flame of a candle was very useful in rendering the atmospheric electricity sensible, when it could not be perceived by means of points; this it probably does, because the effluvium of a candle, which is of a conducting nature, becomes combined with air, so as to form a very complete union; and, as the rarefied air so combined with phlogistic effluvium rises upwards, it is continually succeeded by a fresh quantity; and hence the apparatus has the opportunity of absorbing electricity much more copiously than the sharpest points. Considering this advantage, Mr. *Bennet* provided a deal rod about ten feet long, see *plate* 1, *fig.* 18, and, after the smaller end was well dried, it was fastened into a long tinned iron funnel with cement, so that the funnel did no where come within half an inch of the end of the rod; by this means it is kept dry, and the funnel is not so liable to be accidentally broken off, as if it was insulated by means of glass. At the small end of the funnel is suspended the ring of a chain, which supports a small lantern containing a lighted candle: to the lower and broad edge of the funnel a softened brass wire is fastened, which is about the length of the whole rod; and the lower end is hooked to a small ring near the thick end of the rod, that the wire may not be liable to accidents when the instrument is taken down. When this apparatus is used, a window is opened in the highest room of the house, and the rod is placed upon one strong nail, and under another, on one side of the casement, so that the lantern is elevated about 50 degrees. Near the place to which the rod is fastened is a hole in the window-frame, of sufficient width to receive a tube of glass covered with sealing-wax, on the end of which is a bent wire: the hook of the brass wire is then taken from the ring, and hooked upon this insulated bent wire, which stands at a proper height to be connected with the cap of a gold leaf electrometer, standing upon a board under the wire; and, that the brass wire may not be too much agitated by the wind, a ball of lead is hung upon it. In this situation, it is plain that the atmospheric electricity collected by the candle will come down the brass wire, and be communicated to the cap of the electrometer, or to any other instrument. But, as it very seldom happens that the gold leaf does not diverge when this apparatus is elevated, there is little occasion to make use of a condenser or doubler, or even of a candle, when there are large clouds passing over, or rain falling.

CHAP. XX.

ON MEDICAL ELECTRICITY.

The Abbe *Nollet* says, that he received more pleasure when he discovered that the motion of fluids in capillary tubes and the insensible transpiration of animated bodies were augmented by electricity, than by any other discovery he had made; because they seemed to promise such abundant advantages to mankind, when properly applied by a skilful hand. But, how much would this pleasure have been augmented, if he had lived to see his hopes realized, and this branch of electricity obtain the same medical certainty as the bark in intermittents?

It is true, that like every other simple medicine which has proved beneficial to mankind, electricity met with much opposition from the interested views of some and the ignorance of others, has been treated with contempt, and injured by misplaced caution. I shall recommend to those who thus oppose it, not to condemn a subject of which they are ignorant, but to hear the cause before they pass sentence; to take some pains to understand the nature of electricity; to learn to make the electrical machine act well, and then apply it for a few weeks to some of those disorders in which it has been administered with the greatest success; and there is no doubt but they would soon be convinced, that it deserves a distinguished rank in medicine, which is the offspring of philosophy.

The science of medicine and its practitioners have been reproached with the instability and fluctuations of practice; at one time cold as the ice at Zembla, at another hot as the Torrid Zone; that they are led by fashion, and influenced by prejudice. On this ground it has been predicted, that, however great the benefits which may be derived from electricity, it would still only last for the day of fashion, and then be consigned to oblivion. I must confess, that I cannot be of this opinion, nor easily led to think a set of men, whose judgment has been matured by learning and experience, will ever neglect an agent which probably forms a most important part of our constitution. Electricity is an active principle, which is neither generated nor destroyed; which is every where, and always present, though latent and unobserved; and is in motion night and day to maintain an equilibrium that is constantly varying. To give one instance, among many, it has been shewn, that the rain that descends in a storm is strongly impregnated with electricity, and thus brings down what the heated vapours carried up into the air, till the deficiency of the earth is supplied from the superfluity of the heavens. A variety of other causes concur to vary continually the equilibrium of this fluid; as the perpetual intestine and oscillatory motion, which contributes so much towards carrying on the operations of nature. Further, if a particular portion of this fluid is distributed to every substance, then every alteration of its capacity, which is continually changing by heat or cold, must move or operate on it.

As heat, or fire in action, is the first mover in the animal machine, and the chief active principle during its existence, and as electricity exhibits so many phenomena which cannot be distinguished from those of fire, we are naturally led to conceive high ideas of the importance of this fluid to medicine. Though the vital state of it is not to be estimated by the degree of heat, abstractedly considered, because the degree of heat only ascertains the quantity which is acting in a peculiar manner.

It is known that this vivifying principle hastens the vegetation of plants. Myrtle-trees, which were electrified, budded sooner than others of the same kind and size, and in the same green-house. Seeds, daily electrified, have shot up and grown more in three or four days, than others of the same kind, and alike in all other circumstances, have done in eleven or twelve days. In the same manner Mr. *Achard* has shewn, that it may be used as a supplement for heat, to hatch the chicken from the egg. The supposition of an ingenious writer is by no means improbable, that the vegetating power which is operating during the whole year in ever-greens, may arise from these trees having more resin in their composition than those whose leaves fall in autumn, by which they are enabled to attract and retain those juices which give them their continual verdure, and supply in some degree the absence of solar heat. This may be inferred from their natural properties, and is confirmed by the strong electric power possessed by their leaves. The same writer thinks, that the fluid collected in our electrical experiments is only those solar rays that have been dispersed in, and are arrested by the earth; an idea which is strongly corroborated by the observations made on atmospherical electricity, and by the deductions which have been made from the relative affinities of fire, light, and heat.

The agency of this fluid, and its existence in animated nature, have been fully proved by the experiments that have been made on the torpedo and the gymnotus electricus; for, the similitude established between the electrical fluid of the torpedo and that of nature at large, in such, that in a physical sense, they may be considered as precisely the same. Mr. *Hunter* has well observed, says Sir *J. Pringle*, and I think he is the first who has made the observation, that the magnitude and number of the nerves bestowed on those electric organs in proportion to their size must appear as extraordinary as their effects; and that, if we except the important organs of our senses, there is no part even of the most perfect animal, which, for its size, is more liberally supplied with nerves than the torpedo: nor yet do these nerves of the electric organs seem necessary for any sensation that can belong to them: and, with respect to action, Mr. *Hunter* observes, that there is no part of any animal, however strong and constant its action may be, which enjoys so large a portion of them. If then it be probable, that these nerves are unnecessary for the purpose either of sensation or action, may we not conclude, that they are subservient to the formation, collection, and management of the electric fluid? especially, as it appears from Mr. *Walsh*'s experiments, that the will of the animal commands the electric powers of its organs. If these reflexions are just, we may with some probability foretel, that no discovery of consequence will ever be made by future physiologists concerning the nature of the nervous fluid, without acknowledging the lights they have borrowed from the experiments of Mr. *Walsh* upon the living torpedo, and the dissection of the dead animal by Mr. *Hunter*.*

A variety of curious facts clearly evince, that the electric fire is essentially connected with the human frame, and is continually exerting its influence upon it. Add to this, the ease with which the natural equilibrium is destroyed, and we may readily conceive, that any alteration in the quantity or intensity of action of this powerful fluid will produce corresponding changes in the habit or health of the body. The following is a remarkable instance of the agency of the fluid in the human frame, and of the ease with which it is put in action. Mr. *Brydone* mentions a lady, who, on combing her hair in frosty weather in the dark, had sometimes observed sparks of fire to issue from it; this made him think of attempting to collect the electrical fire from hair alone, without the assistance of any other electrical apparatus. To this end, he desired a young lady to stand on wax, and comb her sister's hair who was sitting in a chair before her; soon after she had begun to comb, the young lady on the wax was surprized to find her whole body electrified, and darting out sparks of fire against every object that approached her. Her hair was strongly electrical,

* Sir John Pringle's Discourses, p. 84.

and affected an electrometer at a considerable distance. He charged a metallic conductor from it, and in the space of a few minutes collected a sufficient quantity of fire to kindle common spirits, and, by means of a small jar, gave many smart shocks to all the company.

Mr. *Cavallo* obtained, by means of a small condensing plate, very sensible signs of electricity from various parts of his own body, and the head of almost any other person.

When the discoveries in this science, says Mr. *Brydone*, are further advanced, we may find, that what we call sensibility of nerves, and many other diseases, which are known only by name, are owing to the bodies being possessed of too large or too small a quantity of this subtile fluid, which is perhaps the vehicle of all our feelings. It is known, that in damp and hazy weather, when this fire is blunted and absorbed by the humidity, its activity is lessened, and what is collected is soon dissipated; then our spirits are more languid, and our sensibility is less acute. And in the fierce wind at Naples, when the air seems totally deprived of it, the whole system is unstrung, and the nerves seem to lose both their tension and elasticity, till the north-west wind awakens the activity of the animating power, which soon restores the tone, and enlivens all nature, which seemed to droop and languish in its absence. Nor can this appear surprizing, if it is from the different state of this fire in the human body that the strictum and laxum proceeds, and not from any alteration in the fibres themselves, or their being more or less braced up, (among which bracers, cold has been reckoned one,) though the muscular parts of an animal are more braced when they are hot, and relaxed when they are cold.

Mr. *Jalabert* and Professor *Saussure*, when passing the Alps, were caught among thunder-clouds, and found their bodies full of electrical fire; spontaneous flashes darting from their fingers with a crackling noise, and the sensations they felt were the same as when strongly electrified by art. It seems pretty evident, that those feelings were owing to their bodies containing too great a share of electrical fire; and it is not improbable, that many of our invalids owe their feelings to the opposite cause.

The perpetual electricity of the atmosphere is no longer a problem: the existence and continual agency of it in that mass of air which surrounds our globe has been ascertained by numerous clear and decisive experiments; and it seems by no means improper to infer, that this fluid cannot exist in the atmosphere without exerting a certain influence on all the beings contained in it, and principally on organized bodies, among which, man holds the highest rank.

EXPERIMENT CCXL. Pass the charge of a large jar, or battery, from the head to the back of a mouse; this, if the shock is sufficiently strong, will kill the animal. After its death, make the discharge in the same manner, and the fluid will pass visibly over the body, and not through it; evincing, that the power or medium which transmitted the shock through the animal is lost with its life. This experiment is taken from Mr. *Cavallo*'s Treatise on Medical Electricity. Its importance is self-evident, and it certainly merits a further investigation by those who are acquainted with the animal economy, as well as electricity.

As the science of medicine knows of no specific, so we are not to suppose that electricity will triumph over every disorder to which it is applied. Its success will be more or less extensive, according to the disposition of the subject, and the talents of those who direct it; it cannot therefore appear surprizing, that many disorders have been refractory to its powers, and others have only yielded in a small degree; or, that the progress of the cure has often been stopped by the impatience or prejudice of the diseased: but at the same time, it must be acknowledged, that even in its infancy, when it had to combat against fear, prejudice, and interest, its success was truly great: we have surely then the highest reason to expect a considerable increase of success, now that it is cultivated and promoted by professional men of the first merit.

In a short course of lectures, which were read on this subject lately by Mr. *Birch*, something like a system was thrown out for the consideration of future electricians. The application of electricity to medicine was divided into three forms; namely, the fluid, the spark or friction, and the shock. The first mode he considered to act as a sedative, the second he ranked under the title of a stimulant, and the last as a deobstruent. As the distinctions were the result of many experiments and much observation, they may safely be adopted for the present. That gentleman being now engaged in the practice of a great hospital, where his electrical experiments have already gained some reputation, we may hope the science will be more universally diffused; and, being taught under the cautious eye of public scrutiny, we may trust its merits will soon give it an established rank in the art of healing.

In medicine, electricity is applicable to palsies, rheumatisms, intermittents; to spasm, obstruction, and inflammation. In surgery, it has considerable scope for action; where contractions and sprains, tumours, particularly of the glandular sort, wasting of the muscles, and other incidents, form a catalogue of visible diseases as distressing to the sight of others as to the patients themselves.

The gout, and the scrophula, or king's evil, two diseases which have tormented mankind and been the disgrace of medicine to the present time, are ranked among those to which this remedy is applicable; and in the commencement of the complaints, I am informed, has been wonderfully successful. To remove ill-placed fits of the gout, it should seem to be a more rational application than any medicine, for it applies directly to the seat of the disease, with a power and rapidity unknown in physic, and perfectly manageable at discretion; and, as it is a remedy which applies to the understanding as well as to the feelings, I should think it better worth the attention and contemplation of men of liberal education, than the compounding a medicine in which they place little faith, or applying a plaister in which they have none at all.

The success of electricity, in relieving the sufferings of mankind, has been considerably promoted, and its operations rendered more rapid, sensible, and efficacious, by applying it in different manners and quantities to the human frame. The modes formerly used were the shock, spark, and sometimes, though very seldom, simple electrification. These modes are now varied, and their number augmented. The stream of the electric fluid may, without a shock, be made to pass through any part of the body; it may also be thrown upon, or extracted from any part, and its action in each case varied, by causing the fluid to pass through materials which resist its passage in different degrees; it may be applied to the naked integuments, or to the skin covered with different resisting substances; and its power may be rarefied or condensed, confined to one spot or applied in a more diffusive manner, at the discretion of the operator.

The apparatus necessary for this purpose is simple, and consists of the following articles:

1. An electrical machine, with an insulated cushion, properly constructed to afford a continued and strong stream of the electrical fluid.

2. A stool with insulating feet, or rather an arm chair fixed on a large insulating stool. The inside part of the back of the chair should move on a hinge, that it may occasionally let down to electrify conveniently the back of the patient: the arms of the chair should also be made longer than usual.

3. A Leyden jar with an electrometer.

4. A pair of large directors, with glass handles and wooden points.

5. A few glass tubes of different bores, some of them with capillary points.

To these may be added, an universal discharger on a large scale, a pair of small directors with silver wires, and a pair of insulating forceps.

Fig. 93, *plate* 5, represents the directors; the handles are of glass. A is a brass wire with a ball on its end. The wire of one is bent, for the more conveniently throwing the electric fluid on the eye, &c. The balls may be unscrewed from the wires, and the wooden point, B, screwed in its place; or the pointed end of the brass wire may be used. The directors should always be held by that extremity of the glass handle which is farthest from the brass, and care should be taken that the heat of the hand does not make them moist.

L and M, *fig.* 84, represent glass tubes, through which small wires are made to pass, to convey the fluid directly to the ear or throat.

Fig. 88 represents another glass tube, of a larger size, the end of which is capillary; a small quantity of rose-water, or any other fluid, is to be poured into this tube; then connect it with the prime conductor by a wire; turn the cylinder, and a subdivided, gentle, and refreshing stream of this fluid may be thrown on the patient.

Fig. 86 represents the insulated electric forceps: some operators think it a very convenient instrument for communicating a shock. Its use and application are evident from an inspection of the figure.

Fig. 85 is the medical jar, furnished with an electrometer, to limit the force of the shock, and enable the operator to give a successive number of them of the same force. C is a bent piece of glass, on the upper part of which is cemented a brass socket, D, furnished with a spring tube, E; the wire, F, moves in this tube, so that the ball, G, may be set at a convenient distance from the ball, H. The end, I, of the bent piece of glass is also furnished with a spring tube, which slides upon the wire, K, communicating with the inside of the jar.

To use this jar, place the ball, H, in contact with the conductor, or connect them together by a wire, and then charge it in the usual manner. Now, if a wire proceeds from the ball, L, to the outside coating, the jar will be discharged, whenever the fluid has acquired sufficient force to pass through the space of air between the two balls; consequently, the shock is stronger in proportion as the distance between the two balls is increased.

It is obvious, that when the electrometer is thus connected, it acts in the same manner as a common discharging rod, and forms the communication between the outside and the inside of the jar; with this difference only, that the distance of the end which is to communicate with the inside may be limited and regulated.

It has been found more convenient, to separate the electrometer from the jar, and apply it to the conductor: see in the frontispiece to this Essay, where *a b* represents the electrometer; *c d*, the Leyden jar, suspended at a small distance from it;

a glass tube, *ef*, is fixed in this bottle, a small part of the lower end of which is coated; two wires pass through the brass ball, C, on the top of this tube, one of which goes down to the bottom of the exterior jar, and touches its internal coating, the other only goes to the coating of the tube: these wires may be removed at pleasure. The jar is to be suspended to the conductor by the ring, and a chain or wire is to be fixed to the hook, *d*, at the bottom.

Fig. 100, *plate* 5, represents the bottle director, which is hollow and coated like a common jar, acting in all respects like one, but is convenient, from its shape and some other circumstances, in giving small shocks.

The handles of the directors should be carefully dried, as also the bent piece of glass C, and those parts of the jar which are above the coating. It is likewise necessary to press the ends of the directors against the part, to convey the shock more readily: by connecting one wire with a positive conductor, and the other with a negative one; or one with the bottom of a Leyden jar, and the other with the electrometer; the shock or stream may be conveyed to any part, with the greatest facility. It is also evident, that a person may, by means of two directors, electrify himself with ease, or any patient conveniently, without the assistance of any other person; that is, he may turn the machine with one hand, while he is receiving the fluid or the shock. But this may also be readily effected, by fastening a wire to one of the conductors, and pinning the other end of it to one extremity of the part through which you intend to pass the shock, or convey the fluid; then connect a director with the other conductor, and hold it to the other extremity of the part. If the situation is such as to occasion the wires to touch the table, pass a small glass tube over them, which will prevent a dissipation of the fire.

Electricity may be applied medically in the following different modes:

1. *By merely placing the patient in an insulated chair, and connecting him with the prime conductor.* When the machine is in action, he will be filled with the electric fluid, which will be continually dissipated from the points and edges of his cloaths; and, though the effects of this are probably too slow to be rendered very advantageous, yet a sedentary person might perhaps derive some benefit from sitting in an insulated chair, having before him an insulated table, the chair to be connected with the ball of a large charged jar or battery; by which means, a small quantity of the fluid will be continually passing through those innumerable capillary vessels, on the right state of which our health so much depends.

2. *By throwing the fluid upon, or extracting it from a patient, by means of a wooden point.* This may be effected in a two-fold manner. 1st. By insulating the patient, and connecting him either with the cushion or the positive prime conductor, the operator presenting the point. 2d. Let the patient stand upon the ground, and the wire of the director be connected either with the positive or negative parts of the machine. The sensation produced by the fluid, when acting in this manner, is mild and pleasing, resembling the soft breezes of a gentle wind; generating a genial warmth, and promoting the secretion and dissipation of tumours, inflammations, &c.

3. *By the electric friction.* Cover the part to be rubbed with a woolen cloth or flannel. The patient may be seated in an insulated chair, and rubbed with the ball of a director that is in contact with the conductor; or, he may be connected with the conductor, and rubbed with a brass ball which communicates with the ground. The friction thus produced is evidently more penetrating, more active, and more powerful, than that which is communicated with a flesh brush; and there is, I apprehend, very little fear of being thought too sanguine, if I assert, that this, when used but for a few minutes, will be found more efficacious than the other, after several hours application. Electricity applies here with peculiar propriety to

spasm, pleurisy, and some stages of the palsy; and in every case answers the end of blistering where the discharge is not wanted, being the most safe and powerful stimulant we know.

4. *By taking strong sparks from the patient.* Here, as in every other case, the operator may connect the ball of the director with the positive or negative conductor; or, he may connect the patient with either of these, and the ball with the ground. Now, it is clear from what has been already laid down, that, if the director be connected with the positive conductor, the fluid is thrown upon the patient; if with the cushion, the fluid is extracted from him. Let the patient be insulated, and the action is in some measure reversed; if he is joined to the negative conductor, or cushion, he will receive a spark from a person standing on the floor; but if he communicates with the positive conductor, he will give the spark to the person on the ground.

5. *By causing a current of the electric fluid to pass from one part of the body, and thus confining and concentrating its operation without communicating the shock.* Place the patient in an insulated chair, and touch one part of the body with a director joined to a positive conductor; then with a brass ball communicating with the ground touch another part, and when the machine is in action the fluid will pass through the required part, from

the conductor to the ball: the force of the stream will be different according to the strength of the machine, &c. Or, connect one director with the cushion and the other with the positive conductor, and apply these to the part through which the fluid is to pass; and, when the machine is in action, the electricity will pass from one ball to the other. It is not necessary to insulate the patient in this case.

6. *By the shock.* Which may be given to any part of the human body, by introducing that part of the body into the circuit which is made between the outside and inside of the jar. This is conveniently effected by connecting one director by a piece of wire with the electrometer, and the other with the outside of the jar; then hold the directors by their glass handles, and apply the balls of them to the extremity of the parts through which the shocks are to be passed. The force of the shock, as we have already observed, is augmented or diminished by increasing or lessening the distance between the two balls, which must be regulated by the operator to the strength and sensibility of the patient. When the little jar with the glass tube is used as a common jar, both wires are to be left there, and the shock is communicated by two directors, one connected with the bottom, the other with the top, by means of the electrometer; see the plate facing the title-

page of this Essay. The operator will often find himself embarrassed in giving small shocks, the fluid passing from the conductor to the ball of the electrometer, instead of going through the circuit he desires: when this happens, which may be known by the chattering noise of the spark in passing to the electrometer, the resistance formed to the discharge is so great, that the fluid cannot force its way through the circuit. To remedy this, and lessen the resistance, pass two metallic pins through the cloathing, so that they may be in contact with the skin; which will lessen the resistance, and conduct the fluid.

7. *By a sensation between a shock and the spark, which does not communicate that disagreeable feeling attending the common shock.* This is effected by taking out the long wire from the small medical jar, and leaving the shorter one which is connected with the tube in its place; the directors to be connected and used as before. In lessening this vibratory shock, the electrometer may be drawn to a much greater distance; for, the rapidity with which the charge of the jar sends forward the charge of the tube is sufficient to overcome the resistance of a large body of air. The effect of this species of shock, if it may be called one, is to produce a great vibration in the muscular fibres, without inducing that pungent sensation which the shock effects. It is, therefore,

applicable to some stages of palsy and rheumatism; it may also serve as an artificial means of exercise.

8. *By the bottle director.* Insulate the patient, and place the ball *g*, in contact with him, by which means this director is charged. Now, if a wire is conveyed from the bottom of this to the top of another director, the bottle director, *plate* 5, *fig*. 100, will be discharged whenever the ball, *h*, is brought in contact with the patient; so that, by bringing it down with rapidity, any number of small shocks may be procured in a minute. Or, connect the insulated patient with the top or inside of a large charged jar, and then this apparatus, used in the foregoing manner, will discharge from the large jar, at each spark, its own contents; and, by repetition, discharge the whole jar. Thus, a number of shocks may be given, without continually turning the machine, or employing an assistant.

9. *By passing the whole fluid contained in the Leyden jar through a diseased part, without giving the shock.* Connect a director by means of a wire with the ball of a Leyden jar; charge the jar either completely or partially, and then apply the ball or point of the conductor to the part intended to be electrified, and the fluid which was condensed in the jar will be thrown on the part in a dense slow stream, attended with a pungent sen-

sation, which produces a considerable degree of warmth. If a wire that communicates with the ground is placed opposite to the end of the director, the passage of the fluid will be rendered more rapid, and the sensation stronger. Or insulate the patient, connect him with the top of a jar, charge this, and then apply a metal wire or piece of wood to the part through which you mean to make the fluid pass. It is obvious, that in this case the circuit between the inside and the outside of the jar is not completed, therefore the shock will not be felt. The condensed fluid passes in a dense slow stream through the required part, while the outside acquires a sufficient quantity from substances near it to restore the equilibrium.

It is in all cases most adviseable to begin with the more gentle operations, and proceed gradually to increase the force, as the strength and constitution of the patient, or the nature of the disorder requires. The stream from a wooden point, a wooden ball, or brass point, may be first used; sparks, if necessary, may then be taken, or small shocks given.

In rheumatic cases, the electric friction is generally used. If the pains are local, small shocks may be given. To relieve the tooth-ach, very small shocks may be passed through the tooth; or, cover the part affected with flannel, and rub it with a director communicating with the machine.

In inflammations, and other disorders of the eyes, the fluid should be thrown from a wooden point: the sensation here produced is that of a gentle cooling wind; but, at the same time, it generates a genial warmth in the part affected.

In palsies, the electric friction and small shocks are administered. Streams of the fluid should always be made to pass through the affected part.

In a former edition of this work, I mentioned that the electrical operations carrying on at a great hospital, under the direction of Mr. *Birch*, had even then gained some reputation. And I ventured to express my hopes, that the science, being taught under the cautious eye of public scrutiny, would be more universally diffused, and that its merits would soon give it an established rank in the art of healing. That these hopes are fully realized, will, I think, be evident from the following letter on the subject of medical electricity, with which I have been favoured by Mr. *Birch*.

A

LETTER

TO

Mr. GEORGE ADAMS,

ON THE SUBJECT OF

MEDICAL ELECTRICITY;

FROM

Mr. JOHN BIRCH,

SURGEON.

SIR,

The pains you have taken to diffuse a general knowledge of electricity, and the unremitting attention you have paid to the improvements of the apparatus, claim the approbation of every one whose study has been directed to the science. I am happy in an opportunity of testifying how much the success of my practice has been owing to the expertness with which you have remedied the defects I found in the machine, as they have presented themselves to me in the course of my experience; for, without your aid I should, like many others, have been tired out by the inefficacy of the instrument, though I should not, like them, have condemned the art for the faults of the artist.

The public have a right to expect from me some account of the result of those experiments in medical electricity, which I have now been more than twelve years engaged in, and in which I could never have so invariably persisted, had I not found it in many cases exclusively eminent and efficacious; for, if it applied only to such diseases as were curable by other means, it would, I am sensible, avail little in practice: but its merit is, that it often affords relief where every other hope is lost, and saves the noble art of surgery from the opprobrium of amputation.

It was not till after several years experience, that I formed in my own mind a system arising from its actions on disease; this system was the result of continued observation; and, as it has enabled me to teach the practice more scientifically, I can have no objection to add it to your useful Essay, and to illustrate it by a series of cases, which will enable the reader to judge of the truth or deception of it. If it should induce those who may have taken up the practice without a sufficient knowledge of the subject, to resume it on better grounds, I will venture to say it will answer their expectations, provided they are masters of the instrument, and are acquainted with the cause and seat of diseases.

The applications of the electric fluid to the diseases of the human body may be all comprized under three heads: the first, under the form of radii, when projected from a point; the second, under the form of a spark, when many of these radii are concentered on a ball; and the third, under that of a globe, when many of these sparks are condensed in a Leyden jar. Now, to each of these heads a specific action belongs: the first, or fluid state acts as a sedative; the second, concentrated state, as a stimulant; and the last, condensed state, as a deobstruent.

Under these three plain intentions, I apply electricity to disease, being guided by anatomy to the distinction of local from constitutional complaints: in the former of which I trust to its power simply; and in the latter, join the aid of the physician and his art.

The apparatus I have also reduced to a simple form, consisting of a moderate sized cylinder, conductor, and Leyden jar, with an insulating chair and electrometer; a glass mounted director with a wooden handle, to the extremity of which a brass ball and wooden point are fitted, and a brass director mounted in wood.

When I wish to apply the fluid, I connect by a smooth wire the glass-mounted director to the conductor with a point at its extremity, and the radii are projected from it to the part affected. When desirous of propelling the sparks, I change the point for the ball. When the shock is intended, the circuit of the Leyden jar must be made. A person insulated may be subjected to a two-fold intention at one moment. Suppose a pain in the eye, requiring a sedative application to the affected part, and the stimulus of a blister at a remote place: the fluid may be flung from the wooden point on the eye, and stimulating sparks may be drawn at the same instant, by a brass ball applied between the shoulders.

By means of the electrometer and these directors, the shock is also manageable to the most exact nicety, and applied to the seat of disease only.

The ingenuity with which these simple modes of application may be varied, to puzzle and deceive the observation of a by-stander, is unbounded, and would have formed a grand basis for empiricism, if they had been artfully employed; but as electricity has escaped abuses, and, I trust, is worthy the serious attention of every practitioner, I submit the following cases to the candour of the public for their determination, whether I have followed an idle pursuit, or dedicated my hours to an important object, that has already proved in no inconsiderable degree beneficial to mankind.

Cases of the electric power applied in the form of radii or fluid.

J. M. aged 18, received a blow from a hammer on his thumb, the pain of which extended up his arm; the flexor muscles were in a short time thrown into such strong action, that the fingers were immoveably contracted. The proper remedies, both internal and external, were ineffectually applied for several weeks; the lad was then sent to St. Thomas's Hospital, under the care of Mr. *Chandler*, who, finding his applications unserviceable, sent him to the electric room for my opinion. In the presence of several of the young gentlemen, I placed the lad on the insulated chair, and, connecting him to the prime conductor, I drew the electric fluid from the fore arm by a needle point. In about three minutes he complained of uneasiness in the flexor muscles of the fingers; immediately the fingers began to extend, and in about five minutes he had the complete use of them.

The indention in the palm of his hand was considerable, from the length of time the fingers had been contracted. I prognosticated this effect would not be permanent; it continued, however, till the hour of rest, but in the morning the hand clenched. This readily gave way to the re-application of electricity the next day: on the third day the spasm returned, but in a much slighter degree: the same application was continued for six days, when, the muscles appearing to have recovered their tone, it was desisted from. Some appearance of relapse being observed on the tenth day, electricity was resumed, and continued for several successive days; and at the expiration of a month, the lad was presented from the hospital well. About fourteen days after, he returned to the hospital with his fingers again contracted, owing to an exertion he had made in the use of a hammer at a smith's forge. Electricity was applied as before, and with the same good success. The young man who had the conduct of the machine, choosing to depart from the system I recommended on the third day, drew some sparks, and passed a few slight shocks through the muscles of the fore arm, which immediately caused the contraction of the fingers, and so strong, that they could not overcome it by the fluid for the three succeeding days. I was then acquainted with the fact, and putting the machine into high order, I drew the fluid from the hand and arm for about six minutes; I then perceived a tremulous motion take place in the flexors, which was followed by an extention of the fingers one after the other; the antagonist muscles then acted so forcibly as to bend back the fingers; a perfect relaxation of spasm next took place, and the lad was relieved as usual. I directed this gentle treatment to be continued every day for a fortnight, when he was again discharged from the hospital cured.

A shopman of Mr. *Baratty*'s, of Fish-street-hill, had been three years afflicted with a coldness and total loss of the use of his lower extremities; he had gained no relief from the advice and remedies he had used, and therefore was sent for my opinion. Upon examination of the spine, I found no reason to conjecture it depended on any affection of that part; the disease had gradually come on from a chill, after heating himself in a summer's day; he was otherwise well in health: I therefore thought the electric friction or shock might probably be serviceable, and I put them in use. The first week I made powerful frictions, but with no advantage: the week following I used shocks, and increased them from day to day, but the patient was not better; however, he felt no inconvenience from the experiment. I then proposed to him, that for one month he should regularly suffer me to draw the fluid only through the affected limbs; and I had not adhered to this simple experiment more than one week, before evident advantages were perceived: I determined therefore not to alter my plan, and within the month proposed my patient was able to walk with the help of a stick only.

Somebody advised him to use cold bathing, but he staid so long at the edge of the bath, that no re-action followed the use of it, and his extremities again failed him. He applied to me, and I put the same method of electricity in use, with equal good success; the patient obtained a perfect cure.

A young gentleman, whilst a pupil at St. Thomas's Hospital, had an eruption of his face, which followed a fever, and which had resisted all the advice and treatment of eminent abilities. It appeared in small blisters, which broke and scabbed, and were extremely unpleasant in their appearance. I persuaded him to let me try the experiment of drawing the electric fluid through the parts; to which he readily submitted, though he laughed at the proposal. The instant relief he found, from its first application, changed his ridicule into hope: he was glad to repeat it every day, and in one week he was well. Some weeks after he was fishing, and exposed to the power of the sun, which renewed the blisters: he called on me that day, was electrified a few times, and relieved as before.

Mr. *A*—— having been a great while under the care of my friend, Dr. *Huck*, for an eruption on his hands and fingers, without the least relief, came at length to consult me, by the Doctor's desire. The eruption had been suspected to be the itch and scurvy, and had been treated accordingly at different times: the discharge was copious, the skin stiff, and the fingers unpliant. It was in vain to propose unguents or lotion, I knew the skill of Dr. *Huck* had left none untried; I had only to propose the experiment of the electric fluid, which immediately gave so pleasant a feel to the skin, and rendered for a short time the fingers so pliable, that the patient and myself were equally surprized at the effect. I requested that no application should be made externally or internally, I applied the fluid only once a day, and in a fortnight he was quite well, and has remained so ever since.

About two years since, this same gentleman finding a little girl, about nine years old, affected exactly in the same manner, recommended her to my care. I applied the electric fluid in the same manner, and she was cured in one week's time.

An infant under three months, who had sucked her mother during an inflammatory fever, was so exhausted, that Mr. *Crawfurd* thought it inpossible she could survive the day. The mother had recovered, but was in a very weak state; the child had lost all febrile symptoms, and had formed a critical abscess near the knee, but the powers of life seemed to be exhausted to such a degree, that the infant was incapable of taking sustenance, or refreshing itself by sleep. In this state Mr. *Crawfurd* thought it would be a very fair experiment, to try if the electric fluid would as it were re-animate the system. The nurse being seated in the insulated chair, the fluid was drawn through the child for a few minutes: the languid pulse was evidently strengthened, the child went almost immediately into a quiet sleep, which lasted two hours; on waking, it took the breast, then slept again; in the evening it was most clearly better. I electrified it again; sleep and food alternately occupied it till the morning. From this time the child throve and grew strong: the abscess in a few days pointed, I punctured it, and discharged an ounce of good pus; two other abscesses formed, and at least an ounce of matter was discharged from each: daily electricity was continued, the abscesses were only kept clean, and dry lint applied to them: the Peruvian bark was given to the mother. Notwithstanding this large depot of matter, the child mended daily, the punctures healed kindly, and the child recovered.

Two years after I inoculated it for the small-pox.

An infant of six months, remarkably healthy, and born of very healthy parents, was inoculated in the spring of the year 1780, and had the small pox very favourably; she was purged afterwards, and returned home. In about two months, the lymphatic glands in the neck appeared tumid, the child lost her appetite, her fæces were of a bad colour, she fell away, and the tumours increased, Dr. *Hebberden* was consulted; and, after the child had taken the medicines he directed for some weeks, without any relief, I waited on him, to know his opinion of the case: with his usual perspicuity and candour he told me, he thought the child must die, because the glands of the mesentery appeared to be as much diseased as those of the neck, which now were suppurating. For a dernier resort, I proposed to him a trial of the electric fluid; to which he readily assented, as from that mode of application he thought no harm could result.

The next day I placed the nurse in the chair, with the child in her lap; I tied the wire, connected with the prime conductor, to the infant's hand, and drew the fluid through the tumours; I next presented it to the abdomen, and continued the operation a few minutes: the sensation appeared agreeable to the child, for she smiled and played during the whole time: as she rode home she fell asleep; on waking, she took nourishment, appeared more cheerful during the evening, and rested well at night. In a very few days,' there was a visible alteration in the child's spirits and general appearance; the tumours, which I thought would burst every night, did not discharge till the tenth day; she then gained appetite and strength: I applied nothing but dry lint to the ulcers, and continued to draw the electric fluid through them daily; they healed quickly, the surrounding glands diminished, the abdomen grew soft, and in about two months she was recovered. The summer advancing, I advised sea-bathing, which was accordingly put in use; the girl has been since in perfect health, and no marks of scrophula have ever appeared.

A servant maid in my neighbourhood was seized in the autumn of 1781 with a constipation in the bowels. The first day she kept her complaints from the family; the next, she was so ill, that the apothecary was sent for. He endeavoured, by five purgative doses given at proper intervals, to open a passage; on the third day, the medicines being ineffectual, a clyster and the warm bath were administered; nothing succeeded, her pain was extreme, her pulse very quick and low; she began to vomit. In this extremity, it was proposed to electrify her; she was brought into my house, and placed in the insulated chair. I connected the chair to the prime conductor by a wire, and drew the fluid through her cloaths with a steel point. She instantly complained of a burning heat all over her body; in less than two minutes, the pain in her bowels increased so violently, that she fainted; on her recovery she felt quite easy, and was in such a hurry for an evacuation, that she could scarce reach the convenience. After this, she was carried to her bed and fell asleep. In about four hours after, her pain and constipation returned; I directed her to have the experiment repeated; it was followed with the same success, a second evacuation was produced in five minutes: her medicines now took effect; their operation, as may be supposed, was violent. The rest of her cure remained with the apothecary: she recovered in a few days.

A lady upwards of 70 years old, of a firm and healthy constitution, after a fit of the gout, had her foot and ankle swelled and weak; she hoped the advantage of country air and exercise would restore it, but she got no better. As she passed through London, she consulted me: I persuaded her to let me pass the electric fluid from a point through the affected joint; she complained of feeling a creeping sensation up her leg as I was electrifying the ankle; it was then evening, she grew hot and restless, slept ill that night, and the next morning was surprized with an eruption of the catamenia. I was not alarmed at this, as I had known similar circumstances; I requested her to keep at home and do nothing: after the third day they disappeared; the swelling of her foot subsided, she recovered the strength and use of the limb, and returned into Sussex perfectly well.

By friction.

Intermittent complaints were extremely frequent in the years 1780 and 81, insomuch that the failure of the Peruvian bark, which had been considered as a specific in this disorder, was remarked by many practitioners, and hence the red bark was introduced.

Several patients were submitted to the experiments of electricity, when other means failed of success; and the result of repeated experiments was remarkable.

A young man, aged 22, had been six months afflicted with an ague, which at its commencement was a tertian, and degenerated into a quartan ague; he had taken the cortex, and various other remedies without success; he was much emaciated: I electrified him with frictions, directed him to try the bark again, and to come when he expected his next fit. The bark would not stay upon his stomach, but he came on the day he expected his fit, one hour previous to its usual time. I placed him in the insulated chair, and applying the ball of the glass-mounted director, connected to the prime conductor by a wire, to the region of the stomach, I poured a stream of electric sparks into the stomach, and extracted them by a brass ball applied up and down the spine: he perceived himself warm and easy, yet at the expected time his rigor attacked him. I immediately electrified him again in the same manner, and in less than three minutes his rigor ceased: in fifteen minutes the rigor returned, I repeated the operation with the same effect; his pulse now quickened, and the fever came on; he went home and into his bed, the sweat succeeded, and the paroxism ceased: the succeeding day he found himself much better than usual. I continued to electrify him in the same manner the four following days, and his fit did not return; then I directed him to take the cortex in powder, which agreed well with his stomach, and his ague was cured.

Mr. *Saltinstall*, hearing of this case, requested me to electrify a patient of his, who had a quartan ague, which resisted the cortex and other remedies. I applied the sparks to him in the same manner, and at the access of the cold fit, with equal success. After being electrified, the cortex would rest upon his stomach, and his ague never returned.

A servant in my neighbourhood had been for many months afflicted with a quartan ague, for which he had taken a variety of remedies with very little relief. In April 1780, he was tormented with a periodical pain in his head, preceded by shiverings, and attended with fever. A physician directed for him a vomit, and the cortex to be freely taken after it: this judicious treatment however gave no respite to his pain, or alleviation to his sufferings; I was therefore induced from compassion to try the effects of electricity on his case. I insulated him, and passed the stream of electric fluid from the forehead through the back of the head; this speedily gave ease, but only for a few minutes; I then covered the head with flannel, and rubbed the sparks along the os frontis, extracting them from the occiput for a few minutes. This application succeeded, his pain ceased, he passed a comfortable evening, and slept well at night; but about an hour after he rose in the morning, his pain returned as violent as ever: he came, and I repeated the frictions as before, but could gain only a momentary intermission of his anguish. I resolved therefore to try the effect of a gentle shock through the affected part; his pain was instantly removed to another part: I repeated the shock in the direction he pointed; the pain vanished, and never returned. By the advice of the physician, he continued the bark a few days, and recovered his health.

A maid servant was afflicted with a similar complaint, which resisted the bark: I electrified her with the sparks, and stopped the pain. She remained well fourteen days, and then an heavy wash renewed the pain: I electrified her a second time in the same manner, and completed her cure.

A servant in the Temple had been long afflicted with a quartan; I electrified him at the access of the cold fit, by the frictions applied to the stomach and extracted from the spine, and stopped the rigor; no fever ensued, and he remained well one month. When waiting for his master at the House of Commons, he got wet, and his ague returned; he then took a vomit and two ounces of good bark, but his ague continued. I began again with electric frictions, and succeeded in stopping the fit the first time I applied them: I afterwards electrified him every fourth day, for one month, and his ague did not return.

I did not escape myself from an attack of intermittent fever. My friend, Dr. *George Fordyce*, directed me an emetic, and some febrifuge draughts; after the second fit, he ordered the cortex, of which I took an ounce and an half, and I flattered myself with success, for several hours elapsed beyond the expected time of the returning paroxism. Just as I was sitting down to dinner, a nausea and chillness seized me, my pulse quickened, and the fever approached: I ordered my bed to be prepared, but I wished to experience the sensation of electricity under this state of approaching fever; accordingly I was insulated, and frictions passed through the stomach and spine. The feel was vastly agreeable, a glow returned upon my skin, and the quickness of my pulse abated: on my return to the dining-room, I found the effluvia of the table not disagreeable to me, I could have tasted something, but I refrained. I sat by the fire fifteen minutes, and found myself revive: before I went up stairs, I repeated the electric frictions, and when I reached my dressing-room, I was too well to go to bed; so I amused myself with reading for an hour, when I found myself perfectly easy, free from heat or thirst, my pulse quite moderate, and my stomach wishing for food: I took only some tea, with bread and butter; at supper-time I eat some vegetable, and went to bed at twelve quite well.

I continued well the next day, went abroad, and had appetite; I resolved to take no medicine for the sake of the experiment. I passed a good night, but at eight o'clock in the morning I found the fever beginning its attack: I rose immediately, and ran to the machine; I was electrified in the same manner, and the symptoms flew before it. I remained well that day and the next, but the following morning, at nine o'clock, I began again to change; the electric machine was a third time applied to with equal success; and from that period I never had any return of my complaints.

A young lady, during the month of her laying-in, was seized with a paralytic affection of the muscles on one side her face; the eye-lid dropped, and the mouth was drawn on one side; stimulants were applied to the part without relief: when she was able to go abroad, she came to consult me. I covered that side of the face with her shawl, and drew the fluid through it, first with a piece of wood, and a few days after with a brass ball in a wooden handle; the cheek on the affected side was flushed with a beautiful vermilion colour every day, for several hours after the application; in less than three weeks she was perfectly recovered.

These local attacks are not uncommon; and, when unattended by further symptoms, are not considered of much moment.

A young man, aged 23, was seized with a paralysis, which affected his speech and the muscles of his face and arm. Finding little relief from the usual remedies, he applied to electricity; by the use of powerful frictions with a metallic ball, he was completely recovered in about one month.

An old man, who for three years had been groaning under the affliction of an hemiphlegia, and who, though wealthy, had not the heart to apply to a physician for aid, and had too much pride to ask relief from an hospital, came recommended for advice. I insulated him, and put in use powerful electric frictions, which perfectly cured him within one month.

A gentleman, who had been many years an invalid, but who had attained his 60th year, being opposed to a bleak wind, was blighted, if I may be allowed the expression, on the exposed side; the muscles on that side his face entirely lost their action, his eye-lid dropped, his tongue hung slobbering from his mouth, his face was drawn on one side, his speech affected, and his arm and hand benumbed; his leg was but slightly attacked. In this situation he advised with Dr. *Hugh Smith*, who was no inactive practitioner; but during a month he received little or no benefit. By the Doctor's advice, he applied to me: I confess, I despaired of being able to render any relief to this patient, whose habit of infirmity was not unknown to me; but, being urged by a lady of his acquaintance to leave no exertion untried, I ventured on the experiment; and the rather, because this lady, who was an infidel respecting electricity, declared, if her friend's case was relieved, she would give credit to all she had heard. The method I put in use, was insulation and electric frictions, which from day to day gained visible advantage, and in a few weeks established a cure; my patient being able to ride, and take sufficient exercise, besides attending to an intricate train of professional business, which called for his mental exertions. In the long vacation, he journied to Wales, and returned in the winter in much better health than he had been accustomed to enjoy. Every spring, for three successive years, he wished to have a course of electrical operations, which he thought reanimated his nerves. He is at present living, and enjoying a state of health, enabling him to use daily horse exercise, with a cheerful mind and a vigour of health which indicate no probability of his closing the period of his existence speedily.

Cases of the electric power applied in the form of shock.

A boy of 12 years old, in the workhouse of St. Clement's parish, had been left there two years with a fixed jaw, and with an enlargement of the glands from the submaxillary to the clavicle.

He had been in St. Thomas's Hospital without receiving benefit: he took his food through an aperture left by the loss of two teeth; and, excepting this local malady, was in good health and spirits. As it was customary for the children to flock about the machine, I one day passed a moderate shock through the masseter muscles and angles of the lower jaw. On my next visit to the house, the master surprized me with saying, the boy had been able to separate his teeth ever since: this unexpected amendment induced me to repeat the application. On the second repetition, I perceived evident advantage; I therefore daily attended to it, and passed some shocks through the enlarged glands, one of which in about fourteen days, came to suppuration: the discharge from this assisted the relaxation of the jaw, and gave me an opportunity to discover a large portion of diseased bone, which I extracted a few days after. The pain of extracting this portion of the jaw brought on the spasm, which was completely relieved the next day, by the application of the shocks.

The cause of the disease being thus removed, nature effected the remainder of the cure, by dispersing the enlarged glands with the help of electricity, supplying the chasm made by the exfoliation, and restoring the lad, who was very much disfigured by the disease, to a decent and not uncomely countenance; in consequence of which, his parents relieved the parish of his burthen, by apprenticing him to their trade.

A young woman, who came into the work-house pregnant, had been obliged to labour almost bare-foot, during the latter stages of her pregnancy, in cold and wet situations. On her recovery from child-birth, her legs and feet were numbed and cold, her ankles extremely weak and painful; when she attempted to stand, she had great pain in her ankles and trembling. Having recovered her health in every other respect, and the apothecary finding general remedies of no effect, I was desired to try the experiment of electricity. I passed gentle shocks through the ankles, where she described her chief complaint to reside; the pain was instantly relieved, a glow came on the lower limbs, and continued for some hours. On repeating the shocks the next day, the pain was removed to her knees, and did not return to the feet. On the third day, after being electrified, she was able to walk, but the nervous tremblings still affected her: I therefore passed gentle shocks from day to day, from her hands to her feet in cross directions; these quickly removed her tremblings, she gained strength daily, and in a fortnight went out of the house perfectly well.

A fishmonger in my neighbourhood, who had lost the sight of one eye in his youth, applied to me, with an acute pain in his head, which he had suffered for some weeks, and which affected the vision of his other eye. The pain shot from his forehead to the summit of the cranium, and produced convulsive spasm of the upper extremities, which were followed by tremors and great oppression of spirits. Confiding in the notion of the electric shock being harmless, under proper management, I did not hesitate to pass one through the brain in the direction he pointed out, that is, from the frontal sinus to the summit of the cranium. He was instantly relieved from his acute pain, the sight of his eye became perfect, and he thought himself cured as by magic.

Not trusting to the permanency of such sudden relief, I persuaded him to let me repeat the shock; after which I passed others from the summit of the cranium to the vertebræ of the neck, and from the vertebræ of the neck to the hands. I prognosticated his pain would return in a few hours.

In the evening the pain did return, but was neither so violent nor of so long duration. I repeated the shocks the next day: on the third day he said his pain had vanished, but the weight of his hat was irksome to him; on repeating the shocks in the same manner, this symptom immediately disappeared, and he could wear his hat with ease: on the fourth day he was free from all complaints, his pain, his defect of vision, his tremors, and his oppression of spirits had quite left him. I passed the shocks again for the last time, and had the satisfaction to find, a long while after, that his cure remained complete.

A young woman under the care of the late Mr. *Else*, surgeon of St. Thomas's Hospital, had repeatedly strained her wrist; in consequence of which the ligaments were so weakened, and the surrounding parts so enlarged, that she had no use of her hand. I would have undertaken the cure in this state, but Mr. *Else* thought it would give way to the successive applications of steaming, blistering and bandaging. After ten months ineffectual trial of these remedies, he delivered her into my care. She had acquired some small degree of flexion in her fingers, and some little strength in her wrist, but not enough to grasp a knife, or lift the smallest weight. My mode of electrifying her was, passing small shocks through the parts affected every day; she gained sensible advantages each time it was done, and in fourteen days I presented her to Mr. *Else* holding a pitcher in that hand containing two quarts of liquor. In a few days after, she was discharged well from the hospital. After six weeks, she presented herself to Mr. *Else* for inspection; her hand was strong and useful, and free from pain, some little enlargement and stiffness remained about the wrist joint, which yielded to the repetition of the shocks in three days; but, as she was able to execute the work of her service with ease, and to wash and scour rooms, it was inconvenient for her to attend at the hospital longer. Six years after her recovery, she again strained the same wrist, in wringing cloaths; she sought me at the hospital, and I again electrified her in the same manner, and cured her completely. The last application was in the year 1785, and I have seen her within these twelve months perfectly well.

Mr. *Else* being satisfied of the powers of electricity by the preceding case, desired me to take the case of a woman in St. Thomas's Hospital, who, after recovering from a fracture of the knee-pan, by a second fall had injured the patella and its ligament; in consequence of which, considerable tension, pain, and enlargement of the knee-joint, and of the whole limb, ensued. It had continued in this tumid and motionless state for eleven weeks, notwithstanding cataplasms, embrocations, fomentations, and bandages had been put in use.

I ventured to make trial of the electric shocks in this case, and passed several through the joint and through the whole limb, till she was sensible of an unusual warmth, which immediately removed her pain; for three hours after, she felt a remarkable throbbing, and her first sleep was disturbed by the sensation of the shock passing through the limb, a symptom not at all unusual. The next day the swelling was apparently less, and she had placed her shoe on her foot for the first time. I repeated the shocks.

The third day after being electrified, she was able to put her foot to the ground. On the fourth day the swelling had quite subsided, and she was able to walk with one crutch. I would have desisted from electrifying her, as the intention of reducing the size of the limb was answered, but she requested me to continue it, in hopes it would expedite the free motion of the limb. At the end of twelve days, she was able to walk into the street; but, having left off a bandage by my direction, lest it should impede circulation, she perceived a crepitus in moving the limb, which was at some times so considerable as to impede its use, and to produce great pain and some swelling; I therefore applied a proper bandage, which remedied this inconvenience, and she was dismissed from the hospital in a few days after.

The success which followed the application of electricity to the two last cases, induced Mr. *Else* to send for me in the month of June 1779, to a man whom he had taken into the hospital for what is commonly called a white swelling of the knee-joint. The disease commenced about three weeks before his admission; he was first attacked with a sharp pain under the patella, which was followed by a swelling, the agony of which produced a considerable fever, which lasted nine days, and then left a vast enlargement of the joint, with evident fluctuation, the limb contracted and wasted both above and below the knee. On minute examination, the inner condyle of the femur was enlarged; I thought this circumstance an objection to my experiment, but at Mr. *Else*'s desire, I began to electrify him with moderate shocks, which produced an immediate warmth in the part continuing for four hours after. I visited him every day, and repeated the shocks. On the third day, he could set his foot to the ground; the swelling gradually lessened from day to day, the fluid was re-absorbed, the limb gained strength, the muscles filled out, and at the end of the fortnight he was able to walk as far as Tower-hill. On that day he omitted to be electrified, but felt the want of it sensibly; I resumed the shocks the next morning, and continued them to the end of the fifth week, when the tumor of the soft parts was entirely reduced, the contraction of the limb removed, its size restored, and the leg perfectly useful. He was desirous of returning home, and accordingly was presented cured from the hospital.

The enlargement of the inner condyle of the femur was very evident when the tumor of the soft parts subsided; but, on examining the whole limb, I found a similar appearance at the lower extremity of the tibia, and the patient told me, that about ten years preceding, when a boy, he went into the water after strong exercise; in consequence of which he lost the use of his lower limbs, which confined him several weeks to his bed. On his recovery, these two swellings were observed, which had continued ever since without much inconvenience to him.

Mr. *Else* giving little credit to this account, seemed to think the cure incomplete; but I had reason from particular inquiry to think the fact was as the patient related, and therefore it was agreed the man should present himself before us at the expiration of six months, which he accordingly did; and Mr. *Else* was so satisfied of the effects of electricity, as to declare, he would never amputate another limb for this complaint, till it had been properly tried.

In the month of September following, Mr. *Else* desired me to repeat the experiment, which had so happily succeeded in the last case, on a boy, aged 16, who was admitted into St. Thomas's Hospital with a similar swelling of the knee-joint. The lad's account was, that on the 19th of August, whilst sleeping in a chair, he was seized with an acute pain about the knee-pan, which waked him; the joint became immediately stiff, and soon after began to swell; the pain increased, and was attended with a considerable degree of fever for several days: when the tumor had increased to a certain degree, the pain and fever abated, and left him with a useless limb, much contracted, and incapable of touching the ground; the muscles above and below the joint wasted, flaccid, and inelastic. Some blood was taken from the part by leeches, but without any relief.

September 26th, I undertook the treatment of him; I passed gentle shocks, as in the former case, until the part felt a sensible glow of heat. The skin was so much distended, that it had a shining appearance, as if smeared over with the white of an egg; but in four days this appearance left him; the boy found some strength, and much more warmth in his leg.

October 1st, he was seized with a diarrhœa, at that time epidemic; he was speedily cured by the attention of the physician; but this circumstance had no effect on his knee. On the 4th of October, my apparatus broke, and being sent for to Brighton, he was left without any aid till the 16th, at which time I found him precisely in the state I had left him. I then resumed the shocks, the good effects of which were plainly evident, for he could immediately move the limb with acquired facility. He now began to mend very fast; in a few days he flung away one crutch, and shortly after the other.

On the 26th of October, he was able to walk from the Borough to Essex-street in the Strand, and to return home again, with the assistance of only one stick. The swelling changed from the inner condyle of the femur to the external one, with a deep seated fluctuation towards the patella; the limb was restored to its size and power, the contraction almost removed, and the swelling very much abated. I continued the stocks till the 14th of November, when the fluid was entirely absorbed, the contraction removed, the limb was strong and perfectly useful, and the lad being desirous of returning to his business, was discharged from the hospital well.

I examined him the 17th of May, 1780, and was happy to find he had been perfectly well ever since.

A woman was admitted into St. Thomas's Hospital, who had formerly had this swelling of the joint, which had been treated with fomentations, leeches, and internal remedies, and had for some time a discharge by two issues made with caustics on each side the patella. The amputation of the leg had by these means been postponed; but, as the knee was contracted, and the limb wasted and useless, the patient was not unwilling to have it removed, since the inconvenience of it prevented her going to service.

I first thought it proper to try the effects of the electric shock, which happily succeeded in removing the contraction, and giving tone to the muscles of the limb; so that in a few weeks the woman left the hospital perfectly well.

An apothecary in Westminster, who had been attacked with this disease, was cured by the taking repeated vomits of turbith mineral; the effects of which, however, so deranged the stomach, that it never recovered its tone. In the winter of 1783, he was again attacked with a swelling of the knee, the progress of which was extremely rapid, and he was incapable of checking the pain by the comfort of opium, because his stomach rejected both food and physic. In an extremity of anguish, with an high symptomatic fever, dejected spirits, resting his last hope on the relief of Bath waters, but incapable of any motion, he sent for me, having heard of the success I had met with in similar cases. When I got to his house, Mr. *J. Hunter* was expected; I waited to consult with him, and learning the hopeless history of the case from him, I proposed immediately to pass the shock.

The patient was much alarmed at my proposal, conceiving in the agony he suffered, that an electric shock would increase his misery: I thought otherwise, and persuaded him to try the experiment in the presence of Mr. *Hunter*. The shock was not painful, as he expected; on the contrary, he bore several repetitions of it, till the part felt such a glow, as it should do after a well-applied fomentation. I left him rather less in pain, and much satisfied with the experiment. In the evening, I visited him again, found him more easy, with a less frequent pulse; and after having repeated the shocks, he was able to move himself from one side of the bed to the other. He got sufficient sleep that night to refresh him, and was sensibly better in the morning. I repeated the shocks morning and evening: on the second day, he was able to get out of bed and have it made; he slept well that night; his fever subsided; small doses of opium abated the irritability of his stomach. From the third day, he gained apparent advantage each time he was electrified: at the end of a fortnight he was able to ride in a coach to my house: at the expiration of three weeks he returned his visits, walking with the help of one stick: in a month he was perfectly well.

A gentleman who had neglected the cure of repeated herniæ humerales testis, applied to me with a very large scirrhus of one of his testes, which I first attempted to resolve by mercurial friction, by vomits, cataplasms, and other external applications. These active remedies failing of success, I consulted Mr. *Else*, who thought castration the only resource; but, as the spermatic chord was not enlarged, he advised the operation to be deferred till pain approached.

During this interval, I proposed to pass the shock of a jar, which would contain two quarts of water, through the part; the pain of this shock was not so much as I expected; the tumor, though large and pendulous, was lifted by the action of the cremaster muscle tight up to the abdominal ring; a considerable heat was felt for some hours in the part. Nothing further was done for a month, at which period I thought the hardness not so stoney, and proposed to repeat the shock, which was done. He went out of town for another month; at his return, I could plainly perceive the tumor separated into three bodies; I therefore repeated the shock. He went far distant, and did not return to London for nine months, when he sent to me; I supposed it was to fix a time for the operation, but, to my astonishment, it was to shew me the dissolution of the tumor. This cure has remained perfectly well ever since; and if there is any difference between the testes, it is, that the diseased one is rather the smaller.

NOTE.

Take an orange, or an onion, place the directors on its opposite sides, and pass a small shock, it will be conducted round from one director to the other by the fluids in the fruit; but pass a considerable shock from a large jar, it will illuminate the whole body, and pervade every part of it.

Does not this point out the propriety of large shocks, when a scirrhous gland is to be roused into action?

A gentleman, who had been under the care of Mr. *Hunter* for a scirrhous testis, and who was recommended by him to try electricity, applied to me for that purpose. As his habit was weakened by mercurial frictions, which had been put in use, I thought it adviseable to direct him the bark, and to postpone the shock, till he had recovered his strength.

The spermatic chord was free from disease, though the testis was much enlarged, and very hard. I began with passing strong shocks, as in the former case, through the tumor in different directions; but, as his residence was a few miles from London, it was agreed he should visit me twice in a week. These strong shocks were therefore regularly applied at the appointed times, and it was one month before I perceived any alteration, when the tumor began to separate into two bodies. From this time it gradually lessened, the epididymis and the body of the testis being first distinguishable from each other, the testis next becoming softer and diminishing, and the hardness of the epididymis lastly disappearing.

While I was pleasing myself with the hope, that the success of electricity in this case would be a sufficient proof of its superior power to other remedies in local obstructions, the left testis began to be enlarged. I knew not how to account for this, unless from some general affection of the glandular system; and yet, under such a tendency to disease, I could not satisfy myself, why the other testis should have yielded to my local treatment.

While in this state of suspense, I resolved not to try the effect of a shock, till some other symptom should direct me further in the cause. In a little time, an external inflammation appeared; and then I was given to understand, that the radical cure of the hydrocele by caustic had been made on that side by Mr. *Else* some years before; I therefore conjectured, that such part of the tunica vaginalis as had not been destroyed, but had been left adhering to the tunica albuginea, was suppurating. I applied a cataplasm of ferina semin. lini, and the skin burst and discharged. After the inflammation ceased, hardness and tumor surrounded the orifice: I then passed shocks through the diseased part, and covered the orifice of the opening with lint, applying the lotion of a solution of white vitriol over it. After passing the shocks, the discharge was always increased; the hardness disappeared gradually, and when the parts recovered their natural state, the orifice closed.

As I have occasionally the pleasure of seeing this gentleman, I learn from him, that he not only remains well, but that the functions of the parts are restored, and their secretion perfect, though moderate.

A dragoon, who was in St. Thomas's Hospital at the time of my election, had received a contusion on one of his testes, which had terminated in a scirrhus; it had resisted all the usual applications, and he came to the hospital to be castrated. I thought it first adviseable he should take the chance of the electric shock, which was administered daily; and in six weeks I discharged him from the hospital cured.

A serjeant of the Sussex militia was sent to the hospital with a scirrhous testis, which the late Mr. *Bayford* had condemned to the knife; as indeed any experienced surgeon, unacquainted with the powers of electricity, would have done. I thought proper to try the effects of strong shocks in this case, which were accordingly passed through the testis. The first application produced a good deal of pain; on repeating them the third day, some fever arose, and the weather being hot, I sent the man to quarters at Newington, where he speedily recovered. On examining the part at his return, I found the mass of tumor beginning to part into portions; I then began to pass shocks, but considerably smaller than at first. This mode agreed well with him, and the testis was gradually diminishing; but, willing to know if the larger shocks were the cause of his first fever, I passed one; his pain was great, his fever followed. I sent him again out of the hospital till he recovered; on his return, the testis was much diminished, and small shocks daily repeated completed his cure.

A negro servant was admitted into the hospital, under Dr. *Blane*'s care, with a scirrhous testis. The Doctor desired me to try the electric shock, which was administered in the same manner as in the former cases; and he was presented out of the hospital in two months cured.

A coach-painter was seized with so violent an inflammation of the body of the testis, that a liberal use of bleeding, evacuations, and opiates gave him no relief. On the third day, I found it would terminate in an abscess; to prevent which, I proposed to pass small electric shocks through the part, which I accordingly did; the first was followed by some respite of pain. I repeated them every four hours, and the next day the pain and inflammation had so much subsided, that the fear of a suppuration vanished. I continued the small shocks, but less frequent, and at the end of one week the cure was completed.

A man was admitted into St. Thomas's Hospital, with a scirrhous testis. On a consultation, it was supposed he must part with it, but it was judged proper to try the electric shocks first. I passed considerable strong shocks, without any inconvenience to the patient; but the result was not as had been usual; for an abscess, formed I believe in the body of the testis, burst and discharged externally. Electricity was omitted, and a soft cataplasm of linseed applied; the wound healed, but round the cicatrix was considerable hardness and induration. I then resumed the shocks, another suppuration took place, discharged, and would have closed, but I repeated the shocks; and after each time I passed them, the discharge increased and the hardness dissolved. This mode was continued till the substance of the testis seemed in great measure melted away. When all induration ceased, I suffered the wound to close, and the patient left the hospital cured.

I see this man frequently; some years have now elapsed since he was in the hospital; he continues perfectly well.

A gentleman, aged 28, in perfect health, went into the country to pursue the pleasures of the chace; the strong exercise which he used, and the little temptation he met with, made him indifferent about softer pleasures. At length, this indifference amounted to a loss of power; and alarmed at this, he applied to a physician of eminence, who treated him with great judgment, but without success. The medicines all agreed with his stomach, he took them in powerful doses, but no good effects followed them. After the inability had continued twelve months, the physician directed him to apply to me for experiment. The experiment had been tried on animals with success; I therefore passed gentle shocks through both the testes, supposing their deficiency of secretion was the cause of the complaint. These were continued daily, and before the end of one week it was evident their secretion was restored. The patient, however, was so impressed with the *timor animi*, that he chose to continue the remedy a month before he satisfied himself of a perfect cure.

I saw him three years after, when he informed me he continued well.

In the month of November, 1787, a porter of the India warehouses was sent to me by a lady of great humanity for advice, being in a state of melancholy, induced by the death of one of his children. Seven years before, he had been seized in the same manner from a similar event, but recovered from it in a short time without medical aid. In the year 1783, he was a second time seized, and remained in this melancholy state upwards of twelve months, although every proper advice was called to his assistance.

He had been two months afflicted when I first saw him. He was quiet, would suffer his wife to lead him about the house, but he never spoke to her; he sighed frequently, and was inattentive to every thing that passed; his appetite and sleep were moderate, his body regular, and his pulse weak and slow.

I covered his head with a flannel, and rubbed the electric sparks all over the cranium; he seemed to feel it disagreeable, but said nothing.

On the second visit, finding no inconvenience had ensued, I passed six small shocks through the brain in different directions. As soon as he got into an adjoining room and saw his wife, he spoke to her, and in the evening was cheerful, expressing himself as if he thought he should soon go to his work again: I repeated the shocks in like manner on the third and the fourth day; after which he went to work. I desired to see him every Sunday, which I did for three months after, and he remained perfectly well. I then dismissed him, with a request that I might be acquainted if ever he had occasion for advice. In the latter end of August, 1791, the woman again applied to me; her husband had continued well till that time, but then had a recurrence of his melancholy without any proximate cause. As he had apparent feverish symptoms, I did not think him in a fit state for the electric shock; I therefore advised him to apply for medical aid, and to the hospital, if he grew worse, as I was leaving town. I am unacquainted with the sequel.

One of the public singers, from a variety of distressing causes, became extremely melancholy; his disease gained ground upon him so much, that he was totally incapable of taking an employment which a kind friend had procured for him; and was therefore sent to me for advice. He had no fever, his appetite was moderate, his body regular, but his depression of spirits excessive. Considering this in the same light as the former case, I began with passing shocks through the head, about six in number, and directed him to call the next day. He said he had rested better. The shocks were repeated daily; his accounts were daily more favourable. Within a fortnight, he asked me if he should accept an offer to sing at one of the summer theatres; I told him, if he thought himself capable of undertaking it, he should, for employment would divert his mind. He accordingly attended some rehearsals. I electrified him after the first fortnight every other day. He anxiously waited from time to time, to find me at leisure for a conversation, which took place at the end of the month, when I pronounced him well enough to undertake his engagement: he then informed me, that his anxiety had arisen from a wish he had to impress me with the change which the first operation of electricity made in his mind. For some few days, previous to his consulting me, he declared he had at several times determined to put a period to his life; for this purpose he had pensively walked along the banks of the Serpentine river in Hyde Park, when a thought of religion impressed him with the horror of the design. At another time, he had the razor in his hand, when the footsteps of a friend stopped his purpose. He had resolved however to effect it, and was in the most distressful agitation about it, the morning he first applied to me. In the evening of that day, he declared he was sensible of the divine interposition in preventing his wicked design; that he found himself able to return thanks; and this relief of his mind was followed by a refreshing sleep, from which he awoke a new being; that he felt sensible of the powers of electricity every day after its application, being capable of mental exertions immediately. He could not be satisfied, he said, without making this declaration to me, as no one but himself could have an adequate idea of the sudden change the first electric shocks wrought in his mind.

After this conversation I dismissed him, and he fulfilled his engagement that summer with his usual applause.

A gentleman who had been long a patient of Dr. *Monro*, with a moping melancholy, and who had reached the age of 26 without any relief, was brought to me, by the consent of the Doctor, for experiment. As I had passed shocks through the brain with such advantage, I thought this a proper case to carry the experiment as far as prudence would direct. I therefore took a Leyden jar, which contained 112 square inches of coated surface, and passed two strong shocks from it, in directions from the frontal to the occipital bone, and from one temporal bone to the other. The patient was at first surprized, not stunned with the shock, and in a few minutes desired me to repeat it if I pleased. The next day, he sat down with firmness, and as no inconvenience had occurred from the shocks, I increased the strength, and passed two shocks in the same direction as before. On the third day, he was reported to have found no sort of inconvenience or alteration from the experiments; so I ventured to pass the full force of the jar; this likewise produced no other effect than a slight head-ach, which lasted for an hour. I chose to omit two days, and then repeat the experiment; the patient strongly expressing himself satisfied, that this was the most likely means to do him service. I was myself most surprized, that I could practice so boldly, without any serious inconvenience to the brain; and having carried the experiments as far as I wished, I dismissed the patient in the same unhappy state he had so long suffered.

Two years since, I was directed by two eminent physicians to electrify a gentleman who had not secreted a drop of urine for nine days: every means to procure a return of the secretion had been put in use. It was remarkable, that the patient suffered no apparent inconvenience, nor had any particular alarming symptom from this want of secretion. I passed slight shocks from the region of the kidneys to the perinæum, through the urinary passages; in eight hours after, about three ounces of a dark-coloured fluid (not bloody) passed from the bladder; after the second application of the shocks, four ounces of a fluid, having the colour, but not the smell of urine, passed in a few hours: the next day, he was electrified morning and evening, and passed about twelve ounces of urine; the following day it increased to a pint; the fourth day he passed a natural quantity and seemed well. However, the shocks were continued a few days longer, during which an eruption appeared on the skin. I then took my leave, and have the pleasure of knowing the patient has continued well.

The same year, a gentleman in good health, and of regular habits, aged about 50, was seized with a palsy of his urinary bladder; for several days his water had been regularly drawn off by the catheter: he had been duly attended, and well advised by an eminent physician and a surgeon, and was at that time taking a course of tincture of cantharides, without any relief: the parts began to grow tender with the passing of the instrument. I passed a stream of electric sparks from the pubis to the perinæum, and along the inferior part of the spina dorsi, for three days, without any relief: I then passed gentle shocks in the same direction, and in three hours after he was able to expel some urine by the muscular power of the bladder. I saw clearly this was the mode to be pursued; I repeated the shocks with daily advantage; in a fortnight the cure was completed, the patient rode on horse-back, went a long journey, and has remained well ever since.

An elderly gentleman, whose faculties were gradually leaving him, had a relaxation of the muscular coat of the bladder, which rendered his company offensive to his visitors and attendants. As I foresaw the inconveniences which would result, being at that time called to him for excoriations, I proposed passing some gentle electric shocks through the bladder, in hopes of restoring its tone. I was permitted to carry my advice into execution: he went out in his carriage after the operation, and did not wet himself during his ride; the shocks were repeated in the evening, and he held his water the night. The next day, his pulse was too quick and his head confused; I did not therefore repeat the shocks, concluding they had occasioned these symptoms. Towards night these symptoms abated, and, as the bladder had recovered the retentive power, I had no further occasion to repeat electricity.

A lady upwards of 70 years, attacked with a paralysis, which gained upon her, notwithstanding the most able assistance, from the involuntary flow of urine, was much excoriated: I was desired to attend her on this account, and was asked to electrify her for her palsy. Her extreme debility, and the space of time she had laboured under her increasing disease, rendered all prospect of recovery hopeless; I therefore proposed to confine my endeavours to the relief of that symptom which was becoming so prejudicial to her, and passed a few shocks from the os pubis to the coccigis, directing proper applications to be made to the excoriated places. Finding no inconvenience result from the shocks, the next day I repeated them more strong, and this was followed by apparently good effects, as she did not wet herself that day. I continued the same mode for a few days; the advantages were daily more favourable, the excoriations healed in proportion as their cause diminished. I then thought I might interrupt my constant attendance, but the first day's absence reproduced the complaint; the bladder lost its retentive power, and her spirits were remarkably low; she would not speak the whole day, ate little, and slept ill. Within an hour after I had electrified her, the following day, she spoke, grew more cheerful, and kept her water till night. I found a constant attendance necessary, and visited her upwards of eight months. Every day, after being electrified, she would speak, appear more cheerful, take her food, keep her water, and sleep well at night; but before I came, she was speechless, shewed great marks of insensibility, and was averse to all the endeavours of her attendants to assist her. I was once obliged to absent myself two days; during this short interval, they all thought she would have expired: on my application of electricity, she revived again. Thus the electric power seemed to keep life vegetating; and this seemed the only power it had, nature being too much exhausted to co-operate with it: however, it certainly made her exit comfortable, and the last periods of life supportable. The mortification, which usually follows the urinary excoriations, is as offensively disagreeable to the attendants, as distressing to the unhappy patient.

On Sunday, the 3d of May 1789, a labouring man in a fit of despair hanged himself with his silk handkerchief, but, being discovered by a watchman, was cut down before his life was extinguished; how long he had been suspended, was not to be ascertained with any accuracy. He was conveyed to a house, where all possible assistance was given by a gentleman of the faculty; about ten o'clock the next morning he was brought to St. Thomas's Hospital, where Mr. *Johnson*, jun. of the Minories, was on duty. At the time of his reception he was insensible; his breathing was laborious, noisy, and performed seldom; his pulse was slow and intermittent, his countenance indicated an accumulation of blood in the head, and he was incapable of swallowing any fluid. Mr. *Johnson* first opened a vein in the arm, and with much difficulty obtained between five and six ounces of blood: this evacuation producing no sensible alteration or effect, he thought an electric experiment might with great propriety be tried; he accordingly passed an electric shock from one leg to the other, the effect of which was extremely surprizing; the patient started, opened his eyes, and seemed very much frightened. On repeating the shock, he spoke, the blood left his face and his countenance became pale, his pulse was free and regular, and his respiration easy. The shocks were repeated three or four times more in the space of ten minutes; after the last, a kind of hysteric affection took place, and seemed further to relieve him; his feet became warm, a general perspiration ensued, he became quite rational, and on removing the bandage from his arm it bled freely, and six ounces of blood were taken from it. The patient was kept quiet for three days, and then discharged well from the hospital.

On examining him with respect to what had passed, he said, he recollected immediately after his suspension, to have felt a most oppressive pain in his back, afterwards a pleasing sensation of green fields (colours) before his eyes; from which time he recollected nothing till the electric shock, which he described as balls of fire darting through his eyes. I do not know if this account of the patient's elucidates any thing; but it is evident, apparently, that suspended life was re-animated instantaneously by the shock.

If the foregoing cases are not sufficient to prove the system I have adopted, they must at least evince the advantages of electricity in the practice of surgery; for it is evident, amputation must have been submitted to in some of them, if the experiments had been unsuccessful. I could adduce several more cases to illustrate my meaning, but that I fear to be tedious; and there are already enough on record to have awakened attention.

A mechanical power, which possesses such eminent utility as to lessen the number of surgical operations, is surely deserving the serious attention of every practitioner: that it belongs to the department of surgery, and requires a knowledge of the cause and seat of the disease, to be applied with effect, will, I trust, be readily allowed.

Thus, Sir, having rescued a philosophical apparatus from the hands of empiricism, and given to its *modus operandi* a rational theory, I shall hope that an electrical machine may hereafter be considered an instrument of surgery; and that in such cases as I have experienced its salutary effects, the knife will be withheld, till a fair and candid trial of its powers has been made; after which, we are warranted by ancient authority, as well as long experience, to put the painful part of surgery in practice.

" *Cuncta prius tentata: sed immedicabile vulnus*
" *Ense recidendum; ne pars sincera trahatur.*"

I am,

SIR,

Your humble servant,

JOHN BIRCH.

ADDENDA,

BY THE EDITOR.

OF ANIMAL ELECTRICITY, AND THE DISCOVERIES OF DR. GALVANI OF BOLOGNA.

OUR Author, in the preceding Essays, not having treated on the electricity peculiar to animals; and some very remarkable discoveries having been lately made thereon, I judge it proper, for the information of the reader, to add a short account of the subject to this work.

It is from the remarkable and similar electrical powers of three fishes that the name Animal Electricity has been derived, and to which the names *torpedo*, *gymnotus electricus*, or the *electric eel*, and the *silurus electricus*, are given. From some experiments made by Mr. *Walsh*, and other ingenious electricians, it was found, that whenever a communication is made, by means of substances that are conductors of electricity, between two parts of these fishes and a man or other animal placed in the circuit, as is done with the common charged Leyden jar to form the communication, the man or animal feels a shock similar to that occasioned by the discharge of the Leyden jar. If the circuit be formed of imperfect conductors, or quite interrupted, a slight tremor is felt only by the hand touching the animal, or no shock is received. It is the gymnotus alone that gives a luminous spark, which becomes evident by making a very small interruption of the circuit of communication. No other properties common with artificial electricity have been noticed in them, and every effect ceases with the death of the fish.

A fourth species of electrical fish, said to give strong shocks, was found by Mr. *W. Paterson*, on the coast of Johanna. See Philosophical Transactions, vol. lxxvi.

Dr. *Contugno*, in a letter to Chevalier *Vivenzio*, both of Naples, dated Oct. 2, 1798, relates, that in his attempt to dissect a very young mouse, and first making an incision into the epigastric region, the mouse being situated between his thumb and first finger of the left hand, and the tail between the two last fingers, to his great astonishment, he felt a shock through his left arm, as far as the neck, attended with an internal tremor, and a painful sensation in the muscles of his arm, which caused him in the affright to drop the mouse.

It is to Dr. *Galvani* that we are indebted for the discovery, that a frog dead and skinned is capable of having its muscles brought into action by the application of artificial or atmospherical electricity; and also that independent of these, the same motions may be produced on it, or even a detached limb, by a simple communication between the nerves and the muscles with substances conductors of electricity, and that no motion can be produced if non-conductors are used. It is from this circumstance, that this wonderful property of organized matter has been ranked as animal electricity. Dr. *Galvani*'s discoveries were principally made with dead frogs, but the properties have been verified in a number of other animals.

The variety of experiments as made by him, and the valuable and illustrative ones since made by Mr. *Cavallo*, Dr. *Lind*, Dr. *Valli*, Dr. *Fowler*, and other philosophers, the limits of this work will not admit me to insert here. I shall only give the reader two or three of the most striking experiments, and for a more general and arranged practical account of this subject, must refer him to Mr. *Cavallo*'s Treatise on Electricity, vol. iii. p. 1 to 75, whence these experiments are extracted.

"When the nerves of a frog recently killed and deprived of its integuments, are exposed to an electrified atmosphere, or, in short, are so disposed, as that by the action of an electrical machine, or of any electrified body, a quantity of electric fluid is caused to pass through them, a contraction of the muscles takes place, with a tremulous convulsive motion, which may be reiterated for some hours after. Dr. *Galvani* prepared a frog, having its legs attached to a part of the spine, but separated from all the rest of the body; and observed, that whenever a spark was taken from a large prime conductor of an electrical machine situated at some distance from the prepared part of the animal, those legs moved with a kind of spasmodic contraction, sometimes strong enough to jump a considerable way. It was found necessary to place the prepared legs contiguous to some good conductor not insulated.

" If the electric atmosphere be so strong as to occasion little sparks between the conductors contiguous to the animal, or if it be capable of affecting an electrometer placed near the animal; then even a whole frog, a lizard, a mouse, or a sparrow, will be strongly affected with violent convulsions. When the animal is insulated, and the electricity is made to pass through its body, then a whole living frog is affected by the passage of so small a quantity of electricity as is discharged by a middling prime conductor, that is just capable of affording a small spark. In this case, if a Leyden jar be used, a much smaller quantity of electricity will be found sufficient for the purpose, *viz.* such a charge of it as cannot afford a spark, but that can just produce a sensible divergence of the pendulums of an electrometer.

" But a frog prepared, especially after the manner of Dr. *Galvani*, is affected by an incomparably smaller quantity of electricity. Mr. *Volta* has observed, that so small a quantity of electricity as is absolutely incapable of occasioning a divergence in the most sensible electrometer, but such as may be observed by his condenser of electricity, is sufficient for the purpose. Thus, if a Leyden jar be charged and discharged, and afterwards be disposed so that the prepared frog be placed in the circuit between its inside and outside coating, the passage of that small residuum is fully sufficient to produce the contractions, &c. By being sensible of so small a quantity of electricity, the prepared frog becomes a most sensible sort of electrometer, which perhaps hereafter may be of singular use in some nice electrical experiments."

" Dr. *Galvani* had the curiosity of trying whether the electricity of the clouds produced the same effect on the prepared limbs, as the artificial electricity of the ordinary machines; and for that purpose he extended a conductor from the top of a house to the prepared animal, which was sometimes laid on a table in the open air, and at other times was enclosed in a glass receiver. On this preparation the thunder and lightning produced the same effects as the spark from the electrical machine: the same contractions took place, and they were stronger or weaker according to the distance and quantity of lightning. Thus far the effects might have been naturally expected; but a remarkable circumstance was observed, which serves to explain another phenomenon of nature: it was found, that instead of one contraction at every clap of thunder, the limbs were affected with a sort of tremor or succession of convulsions, which seemed to be nearly equal in number to the repetition of the thunder, *viz.* that succession of explosions which forms the rumbling noise of thunder. Now this observation proves, that the rumbling noise is not the echo of a single explosion, or the successive arrival of the vibrations produced at different distances, though at the same moment of time; but that it is produced by a quick succession of several explosions: which indeed seems to be confirmed by observing, that the clouds are very imperfect conductors, in which state they are not likely to receive a full and single stroke of electricity from other clouds or from the earth."

The preceding accounts relate to dead animals; but it will now be shewn, that the same motions, convulsions, &c. for a time nearly equal in length, can be produced both in dead and living animals, without the aid of any apparent electricity.

"In an animal recently dead, detach a nerve from the surrounding parts; taking care to cut it not too near its insertion into the muscles; remove the integuments from over the muscles depending on that nerve; take a piece of metal, as a wire, touch the nerve with one extremity, and the muscles with the other extremity of the wire, and the consequence will be, that the muscles will move exactly as if a quantity of electricity were sent through them. This experiment will answer equally well when the preparation is laid upon an insulated stand, as when it communicates with the ground. If the communication between the nerve and the muscles, instead of being formed by means of metal or other conductor of electricity, be formed of substances that are non-conductors, as glass, sealing-wax, oils, &c. then no motion will take place."

"The motions will be also excited when the metals are not in immediate contact with the prepared limb, provided they form part of the circuit of communication. Thus lay a prepared limb upon a table, hold the nerve in one hand and a piece of zinc in the other hand; lay a piece of silver upon the table at about one or two inches distance from the prepared muscles, and make a communication between the muscles and the silver by means of water or some other good conductor. If now you touch the said piece of silver with the zinc which you hold in one hand, the contractions will take place. The same effect will happen, if the two pieces of metal be first put in contact, and then the operator touches the nerve of the preparation with his finger.

"The preparation of the frog, or other animal, for this experiment, generally consists in detaching one of the principal nerves from all the surrounding parts, where it enters a member susceptible of motion, and arming it with a metallic foil. On making the communication, the motion will take place; but the preparation which answers best is delineated in *pl.* 5, *fig.* 104 and 105, which, for the sake of distinction, we shall in the following pages call the *usual preparation*; it being, in fact, that which has been more frequently and more advantageously used: it is made in the following manner. Separate with a pair of scissars the head and upper extremities of a frog, in the line A B, from the rest of the body. Open the integuments and muscles of the abdomen, and remove the entrails; then you will lay bare the crural nerves, as shewn in *fig.* 104, which in this animal come out of the spine at a considerable distance above the pelvis, *viz.* from the line C D. Then pass one blade of the scissars under the said nerves, and cut off the spine with the flesh close to the thighs in the line E F, by which means the legs will remain attached to the spine by the nerves alone. This done, leave only a small bit of the spine attached to the crural nerves, and cut off all the rest. Thus you will have the two legs, G, H, *fig.* 105, of a frog adhering to a bit of the spine A C D, by means of the crural nerves C E, D F. These legs must be flayed in order to lay bare the muscles. The metallic armour, which generally consists of a piece of tin-foil, must be placed round the nerves very near the spine, *viz.* at C D, or round the whole bit of spine, A D, and the extremities of the nerves next to it. A frog thus prepared, and touched by means of a conducting rod applied to the muscles and to the armour of the nerves, will act vigorously for a considerable time. Some contractions have been observed several hours, and even days after; but the power is gradually diminishing, and in general it can seldom be perceived after two or three hours.

" With a frog prepared in the above described manner, one may shew the experiment various ways; but the two following methods are peculiarly eligible, because they produce very strong and striking movements. Hold the preparation by the extremity of one leg, the other leg hanging down, with the armed bundle of nerves and bit of spine lying upon it. In this situation interpose a piece of silver, as a half-crown, between the lower thigh and the nerves, so that it may touch the former with one surface, and the metallic coating of the latter with the other surface, or with its edge; and you will find that the hanging leg will vibrate very powerfully, sometimes so far as to strike against the hand which holds the other leg.

"The other method is the following: Put two wine-glasses full of water contiguous to each other, but not actually touching. Place the thighs and legs of the prepared frog in the water of one glass, and laying the nerves over the edges of the two glasses, let the bit of spine and armour touch the water of the other glass. This done, if you form the communication between the water of the two glasses by means of the conducting rod, or put the fingers of one hand into the water of the glass that contains the legs, and, holding a piece of silver in the other hand, touch the coating of the nerves with it, you will find that the prepared legs will move sometimes so powerfully as to jump fairly out of the glass. It is however necessary to remark, that the effect in this experiment is increased by a sort of artifice, which must necessarily take place; *viz.* the legs, in order to be placed into the glass, must necessarily be drawn up; and, as the effect of the communication, &c. is to produce a sudden extension of the limbs, it must naturally follow, that from the resistance of the glass the preparation must endeavour to jump out of the water. There is another reason which contributes to increase the effect in this experiment, which is, that the water by surrounding the prepared legs, becomes a very ample armour or coating, which touches the legs in every point of their surface. It frequently happens in this experiment, when the animal electricity is strong, that without forming the communication, the motions are excited by only touching the armour of the nerves with a piece of metal; or if one person touch the coated spine, whilst another person touches the legs, the motions will take place, though the two persons do not communicate with each other by any thing else besides the floor."

By the application of armours of different metallic substances, and forming a connexion between them, the motions may be excited in an entire living frog, and also in other living animals, particularly eels and flounders. Mr. *Cavallo* gives the following directions: "A living frog is placed upon a piece of zinc, with a slip of tin-foil pasted upon its back. This done, whenever a communication is formed between those two armours, especially when silver is used, the spasmodic convulsions are excited not only in the muscles which touch the metals, but also in the neighbouring ones. The slip of tin-foil may be omitted when silver is used for the conducting rod. The experiment may be performed entirely under water.

"This experiment may be made with a flounder in a similar easy and harmless manner. Take a living flounder, such as can almost always be found at the fish-mongers, lay it flat into a pewter plate, or upon a sheet of tin-foil, and put a piece of silver, as a shilling, a crown-piece, or the like, upon the fish; then, by means of a piece of metal, complete the communication between the pewter plate or tin-foil and the silver piece; on doing which, the animal will give evident tokens of being affected. The fish may afterwards be replaced in the water to preserve it for farther use." Dr. *Fowler* has proved, that of the involuntary muscles, the heart alone is capable of being contracted.

"Even the living body (says Mr. *Cavallo*) can be rendered sensible of the action of metallic applications, and both the senses of taste and sight be excited by it. Let a man (says he) lay a piece of metal upon his tongue, and a piece of some other metal under the tongue; on forming the communication between these two metals, either by bringing their edges into contact, or by the interposition of some other piece of metal, he will perceive a peculiar sensation, a kind of cool and subacid taste, not exactly like, and yet not much different from that produced by artificial electricity. The metals which answer best for this experiment are silver and zinc, or gold and zinc. The sensation seems to be more distinct, when the metals are of the usual temperature of the tongue. The silver or gold may be applied to any other part of the mouth, to the nostrils, the ear, and other sensible parts of the body, whilst the zinc is applied to the tongue; and on making the communication between the two metals, the taste is perceived on the tongue. The effect is more remarkable, when the zinc touches the tongue in a small part, and the silver in a great portion of its surface, than *vice versa*. Instead of the tongue, the two metals may likewise be placed in contact with the roof of the mouth as far back as possible, and on completing the communication between them, a strong taste of irritation is perceived."

"In order to affect the sense of sight by means of metals, let a man in a dark place put a slip of tin-foil upon the bulb of one of his eyes, and let him put a piece of silver, as a spoon, or the like, in his mouth. On completing the communication between the spoon and the tin-foil, a faint flash of white light will appear before his eyes. This experiment may be performed in a more convenient manner, by placing a piece of zinc between the upper lip and the gums as high up as possible, and a silver piece of money upon the tongue; or else, by putting a piece of silver high up in one of the nostrils, and a piece of gold or zinc in contact with the upper part of the tongue; for in either of these cases the flash of light will appear, whenever the two metals are made to communicate, either by the immediate contact of their edges, or by the interposition of other good conductors of animal electricity.

" When this experiment is performed by a person having his eyes open in a place in which there is very little light, a by-stander will generally perceive a slight contraction of the pupil whenever the metals are brought into mutual contact. The experiment will likewise answer, when one of the metals is placed between the gums and upper lip, whilst the other metal is placed between the gums and lower lip; but in this case the flash appears to be diffused over the whole face, whereas in the other case it is confined to the eyes alone. By continuing the contact of the two metals, the appearance of light is not continued, it being only visible at the moment of making the contact, and very seldom when they are separated; it may therefore be repeated at pleasure, by disjoining and again connecting the two metals. When the eyes are in a state of inflammation, then the appearance of light is much stronger. This phenomenon is not alike perceived by every person, some being hardly sensible of it, whilst others observe a strong flash."

The property of animal motion being excited by a metallic or other communication made between the nerves and the muscles, is not considered peculiar to a few animals only; but seems, from a great variety of experiments, to be a property common to all animals. Mr. *Cavallo* observes, " from the ox and the horse down to the fly, the effects of metallic applications have been repeatedly and unequivocally observed. The leg of a recent dead horse was agitated so violently by the application of a shilling and a piece of tinfoil, that the strength of a robust man was unable to check the blow."

I shall end this extract with some observations and inquiries by Mr. *Cavallo*. " Those surprizing effects of an unknown cause, generally inexplicable, and sometimes contradictory, seem to admit of no theory sufficiently probable or satisfactory; nor can we yet see how they may be applied for the benefit of mankind. An attentive consideration of the subject will naturally suggest several doubts and queries, which can only be answered by future experiments and discoveries.— In what manner does artificial electricity affect the muscles?—Does it act as a mere stimulus, or otherwise?—Where is the animal electricity generated, and by what mechanism is it transmitted from one part of the body to another?—Does it proceed from the brain, or is every nerve actuated with that generating power?—What reason can there be for the necessity of using two different metals?—And, after all, are those phenomena really the effects of electricity, or of some other unknown fluid *sui generis?*"

Additional Descriptions that have occurred to the Editor, since the printing of the preceding Sheets.

Townsend's Electrometer. Plate 2, *fig*. 9, represents an electrometer contrived many years since by Mr. *Townsend*, to ascertain the real force of the electric explosion. *a b* is a small ivory plate; *c*, a loose cone of ivory to be placed on the plate *a b*; *e f g*, a circle turning freely on two centers; a wooden arm, *d*, proceeds from this circle, and rests on the ivory cone, *c*. The discharge of the jar or battery is made to pass under the cone which throws up the arm *d*, the elevation of which is marked by the index *h*. A piece of silken string is fixed at one end to the bottom board at *i*, and passes over the wheel; a weight, *k*, is tied to the other end, to regulate the friction of the circle *e f g*.

Nicholson's Improvement on Bennet's Electrometer. Mr. *Nicholson* has improved the electrometer of Mr. *Bennet*, in order to distinguish more accurately the different intensities as shewn by the divergencies of the strips of gold leaf, or the distances at which they strike two metallic bars. *Plate* 4, *fig*. 70, " A represents the insulated metallic cap, from which, at C, depend the two narrow pointed slips of gold leaf. B B is the glass shade, which serves to support the cap, and defend the leaves from the motion of the surrounding air. D D are two flat radii of brass, which open and shut by means of one common axis, like a pair of compasses. By a contrivance of springs, they are disposed to open when left at liberty; but the micrometer screw, E, serves to draw a nut which has two steel bars, with a claw at the end of each, that enters into a correspondent slit, in two small cylindrical pieces, to which the radii are fixed respectively. This apparatus is seen in another position in *fig*. 70*. K L represents a piece of brass, which serves as a frame for the work, and fits the lower socket of the electrometer F F, *fig*. 70. In this the letters, I H, indicate the cylindrical pieces which carry the radii, and are seen from beneath. On the side of the nut, G, one of the steel drawing pieces is seen; the other being on the opposite side, and consequently not visible. Towards L appear the two re-action springs. The other parts require no verbal description.

" In the common construction of the gold-leaf electrometer, there are two pieces of tin-foil pasted on opposite parts of the internal surface, B B; against which the gold-leaf strikes when its electricity is at the maximum. If the radii, D D, be left at the greatest opening, our instrument does not then differ from that in common use. But if the divergence produced by the contact of an atmospheric conductor, or any other source of electricity, be so small as to render it doubtful whether the leaves be electrified or not, the radii may then be brought very gradually together by means of the screw, until the increased divergency from their attractive force be sufficient to ascertain the kind of electricity possessed by the leaves. In this and all other cases, the division on the micrometer head, which stands opposite the fixed index, at the time the leaves strike the radii, will shew the greater or less degree of intensity."*

Brooke's Electrometer, as constructed by the late Mr. G. A. Morgan. To the description of *Brooke*'s electrometer already given at page 412 the following account as constructed by Mr. *Morgan* may be added, and which he found adapted to various experiments. His reasons for making his different from Mr. *Brooke*'s were the follow-

* *Nicholson*'s Journal of Natural Philosophy, vol. i. p. 270.

ing: " he found that the least difference of charge, when the jar was highly loaded, produced a most amazing irregularity in the effect dependent on the passage of the charge. Hence, though the arm was regulated so as to shew the difference of the grain weights, still he experienced a difficulty in ascertaining *when* exactly the two balls were separated, and he found considerable diversities dependent on the greater or less separation of them; he therefore connected the arm with the hand on the plate, and was thus able to determine accurately the very instant in which the same quantity of charge might be made to pass through any given substance."

Plate 5, *fig.* 87, ABECD represents Mr. *Morgan*'s electrometer, which he employed to measure the precise charge that he conveyed through the body to be examined. CE is a very slight brass tube, with a light brass ball annexed to the extremity of it. The dimensions of the ball are one inch and a quarter in diameter; the tube is eight inches in length, and one inch and a quarter in thickness: this tube is annexed to a multiplying wheel, which is connected with the hand on the dial plate, and by its motions gives four circumvolutions of the hand to every one-fourth of the tube's. The figure shews that the tube rests upon another similar tube, which is fixed. The moveable tube has a slider upon it, which, by moving backward and forward, regulates the weight to be raised, when the electrometer is connected by a metallic communication to the inside of a jar while charging. The insulation of the tube, balls, and the wheel-work annexed to them, are shewn by the figure, in which A B represents the glass stem.

Plate 5, *fig*. 81, is an electrometer for rain, contrived by Mr. *Cavallo*. A B C D is a strong glass tube, about two feet and an half long, having a tin funnel, D E, cemented to its extremity, which funnel defends part of the tube from the rain. The outside surface of the tube, from A to B, is covered with sealing-wax, and so is the part of it which is covered by the funnel. F D is a piece of cane, round which brass wires are twisted in different directions, so as to catch the rain easily, and at the same time to make no resistance to the wind. This piece of cane is fixed into the tube, and a small wire proceeding from it goes through the tube, and communicates with the strong wire A G, which is thrust into a piece of cork, fastened to the end A of the tube. The end G of the wire A G is formed into a ring, from which a sensible pith-ball electrometer is to be suspended. This instrument is fastened to the side of a window frame, where it is supported by strong brass hooks at C B; which part of the tube is covered with silk lace, in order to adapt it better to the hooks. The part, F L, is out of the window, with the end F elevated a little above the horizon. The remaining part of the instrument comes through a hole in one of the lights in the sash, within the room, and no more of it touches the side of the window than the part C B. When it rains, especially in passing showers, this instrument is frequently electrified; and by the divergence of the electrometer, the quantity and quality of the rain may be observed without any danger of a mistake. With this instrument, in rainy weather, Mr. *Cavallo* has been able to charge a small coated phial at the wire H G. It should be fixed in such a manner, that it may be easily taken off from the window, and replaced again, as occasion requires; as it will be necessary to clean it often, particularly when a shower of rain is approaching.

To EXPERIMENT LXXXIX. p. 198. *The method of making the artificial Bolonian stone, or Canton's phosphorus,* which is a calcareous substance, and generally used in the form of powder. "Calcine some common oyster-shells, if they are old and half calcined by time, such as are commonly found upon the sea-shore, they are the better; let the purest part of the calx be pulverized and sifted; mix with three parts of this powder one part of the flowers of sulphur; let this mixture be rammed into a crucible about one inch and an half in depth, till it be almost full, and let it be placed in the middle of the fire, where it must be kept red-hot for one hour, and then set it by to cool; when cold, turn it out of the crucible, and cutting it or breaking it to pieces, scrape off upon trial the brightest parts, which, if good phosphorus, will be a white powder. It may be preserved by keeping it in a dry phial with a ground stopper." A beautiful manner of expressing geometrical figures with the above phosphorus is, to bend small glass tubes of about one-tenth of an inch in diameter in the shape of the figures desired, and then to fill them with the powder. These may be illuminated in the manner described; and they are not liable to be spoiled, as the figures are when exposed on a board. Mr. *Canton* found the discharging of a small jar near to the phosphorus the best method of illuminating it.

To EXPERIMENT CVII. p. 213. *King's electrical orrery, shewing the motions of the sun, earth, and moon, round the common center of gravity. Plate* 4, *fig*. 79, the ball, S, represents the sun, E the earth, and M the moon, connected by bent wires, *a*, *c*, *b*, *d*; *a* is the center of gravity between the sun and earth; *b*, the center of gravity between the earth and moon. These three balls, and their connecting wires, are supported on the pointed wire A, which is placed on the prime conductor of the machine; the earth and moon supported on the pointed wire *c a e*, in which wire is placed a fine point horizontally at *c*, and also a similar one at *d*, projecting out in the same manner in the wire connecting the earth and moon.

When the machine is put into action, the balls and wires being electrified, and the fluid going off horizontally from the points *c* and *d*, cause S and E to move round their common center of gravity *a*, and E and M round their center of gravity *b*. As E and M are light, when compared with S and E, there is much less friction on the point *b* than on the point *a*; so that E and M will make more revolutions about the point *b*, than S and E about the point *a*. The weights of the balls should be so adjusted, that E and M may move about twelve times round *b* in the time that S and E go once round *a*.

This amusing experiment does not shew the real cause of the planetary motion, but only that the sun, earth, and moon, move round the common center of gravity between them in a solar year, and the earth and moon move round the common center of gravity between them in a lunar month.

To EXPERIMENT CXXI. p. 526. *To make eggs luminous*. *Plate* 4, *fig*. 66*, represents a wooden stand to support three eggs, and by the sliding supports, *a*, *a*, *a*, to place them at any required distance asunder. *b*, a brass sliding wire; and *c*, a chain or wire; both as conductors of communication. Three eggs are to be placed at about one-eighth of an inch asunder, the lower extremity of the wire *b* at the same distance, and one end of the chain or wire *c* in communication with the bottom egg, and the other end with the coating of a charged electric jar. With the discharging rod, *plate* 2, *fig.* 2, one ball being placed on the ball of the wire *b*, and the other to the ball of the charged jar, the discharge will instantly pass through the eggs, and in a darkened room exhibit them luminous, more so, than if held to a candle in the common way.

Plate 5, *fig.* 103, represents an apparatus for setting into deflagration by electricity, a fine twisted iron wire, placed in a jar of dephlogisticated, or what is now termed oxygene air. A is a glass jar of about nine inches in height and three inches diameter; B, a metallic cover closely cemented on the top; C, a brass ball and wire proceeding through the top to the inside; D, the iron wire, about the one-thirtieth of an inch in diameter; the upper extremity of which goes into a ball made in the brass piece, and to which any new wire may be readily applied. E is a metal or wooden stand, on which the bottom of the glass jar is placed, after the jar is filled with the oxygene air.* F is a brass piece raised from the bottom, and stands about one-quarter of an inch from the lower extremity of the wire. Now, a chain or wire laid from E to the outside of a charged electric jar, and one ball of the jointed

* For the ready and best method of making this air, see my edition of *Adams*'s Lectures, Vol. i. p. 511.

discharging rod laid on the ball C, and the other to the ball of the charged jar, the discharge will instantly take place, and the passage of the fluid from the lower extremity of the wire, D, to the piece F, will set fire to the wire; and, being exhibited in a darkened room, will burn away to the top with a beautiful sunlike figure in motion, giving a very intense and brilliant light, till the whole wire is deflagrated, and throwing off a quantity of melted particles of the iron.

Of the plate electrical machine. About 40 years ago the ingenious Dr. *Ingenhouz* constructed and first introduced into this country the plate electrical machine, the excitation of which was produced by friction on a circular glass plate, of from about nine to twelve inches in diameter; this plate turned vertically, and was rubbed by four cushions placed at the opposite ends of the vertical diameter. The brass conductor had two horizontal branches coming from it, reaching to within about one-half of an inch of the extremity of the glass, so that each branch takes off the electricity excited by the cushions.

This sort of machine has since been much used on the continent, and but very rarely here. A large and very powerful plate machine has been lately constructed by Dr. *Van Marum*, for the Museum of *Teyler* at Harlem, as well as others of less dimensions in this country. Dr. *Van Ma-*

rum's, the reader will see explained by Mr. *Nicholson* in his Philosophical Journal, vol. ii. p. 83; from whom it appears, that a plate machine carefully and well constructed is, upon the comparison of the excited surfaces, at least equal in steady intensity, and superior in power of charging, to any cylinder which has ever been made.

The Harlem machine consists of two circular glass plates, each 65 inches in diameter, at seven inches and an half apart, fixed parallel to each other, and rubbed by four cushions to each plate. In the Journal, Mr. *Nicholson* has described the simple and powerful plate machine invented by Dr. *Van Marum*, the plate of which is 31 inches in diameter, and produced a very considerable intensity of power.

There were some practical difficulties formerly found in the construction of these plate machines, that are now removed; and I conceive but one objection that can be made by persons who only procure them for the common purposes of instruction and entertainment; that is, that the glass plates, unless managed with the most particular attention in the adjustment of the rubbers, &c. while in action, are liable to be cracked, flying from the center towards the circumference.

FINIS.

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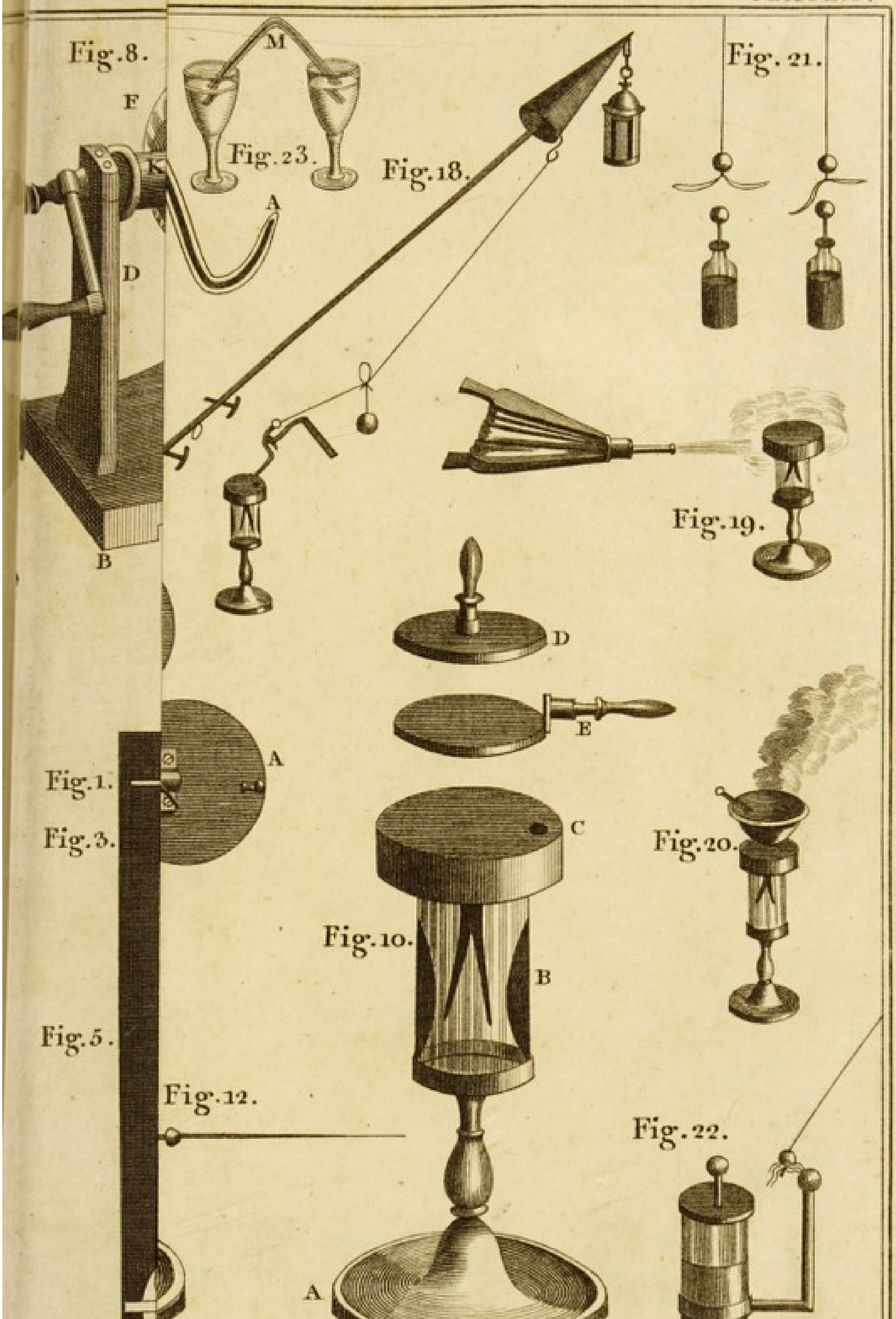
—— 178, — 8, *for* fig. 22 *read* fig. 23.
—— 202, — 4, *for* fig. 35 *read* fig. 33.
—— 281, — 19, *after* same time *add* fig. 67.
—— 290, — 2, *for* phial *read* pail.
—— 357, — 3, *for* fig. 73 *read* fig. 74.
—— 431, — 11, *for* N *read* IV.
—— 475, — 10, *for* fig. 9 *read* fig. 17.

PLATE. I.



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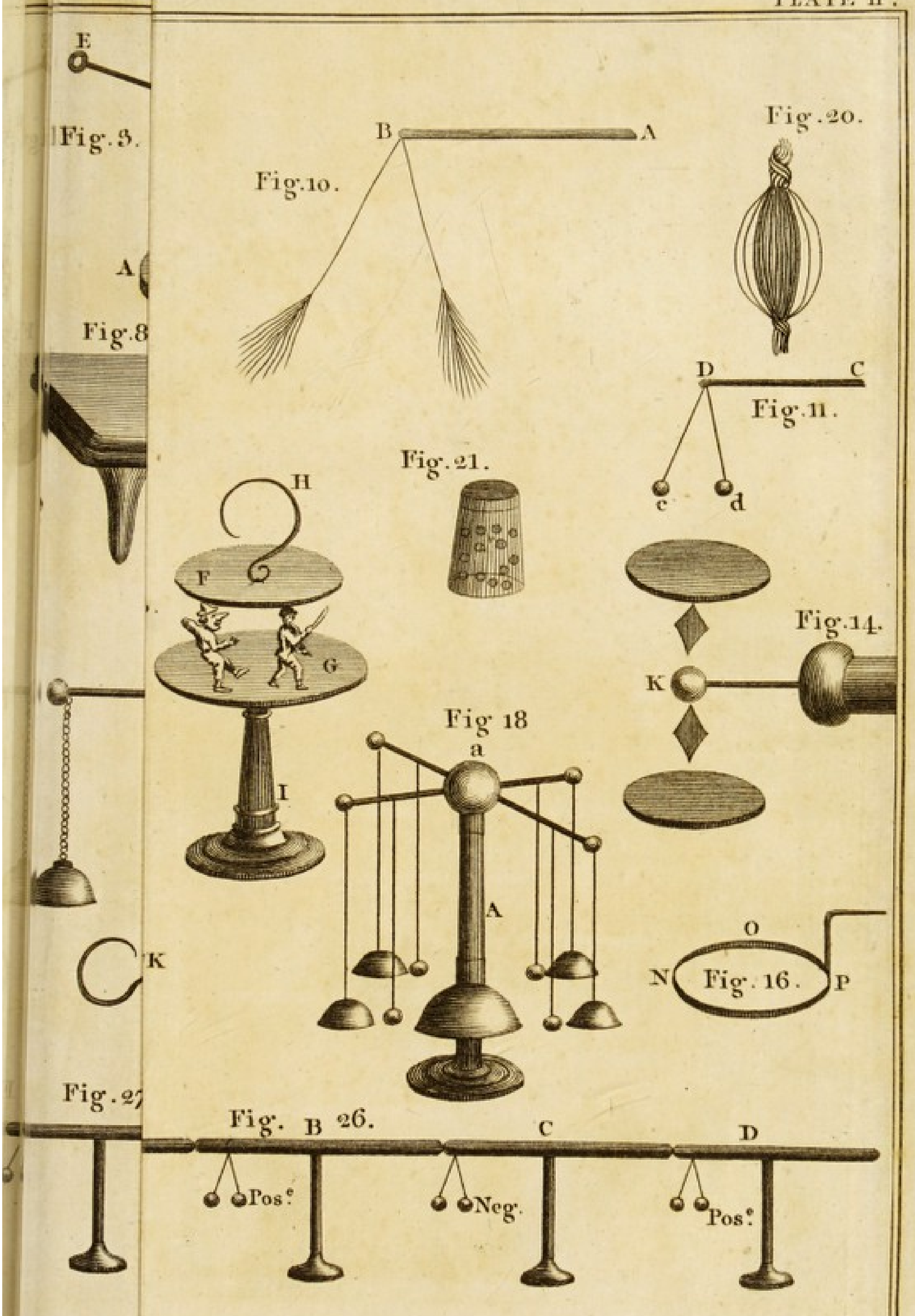

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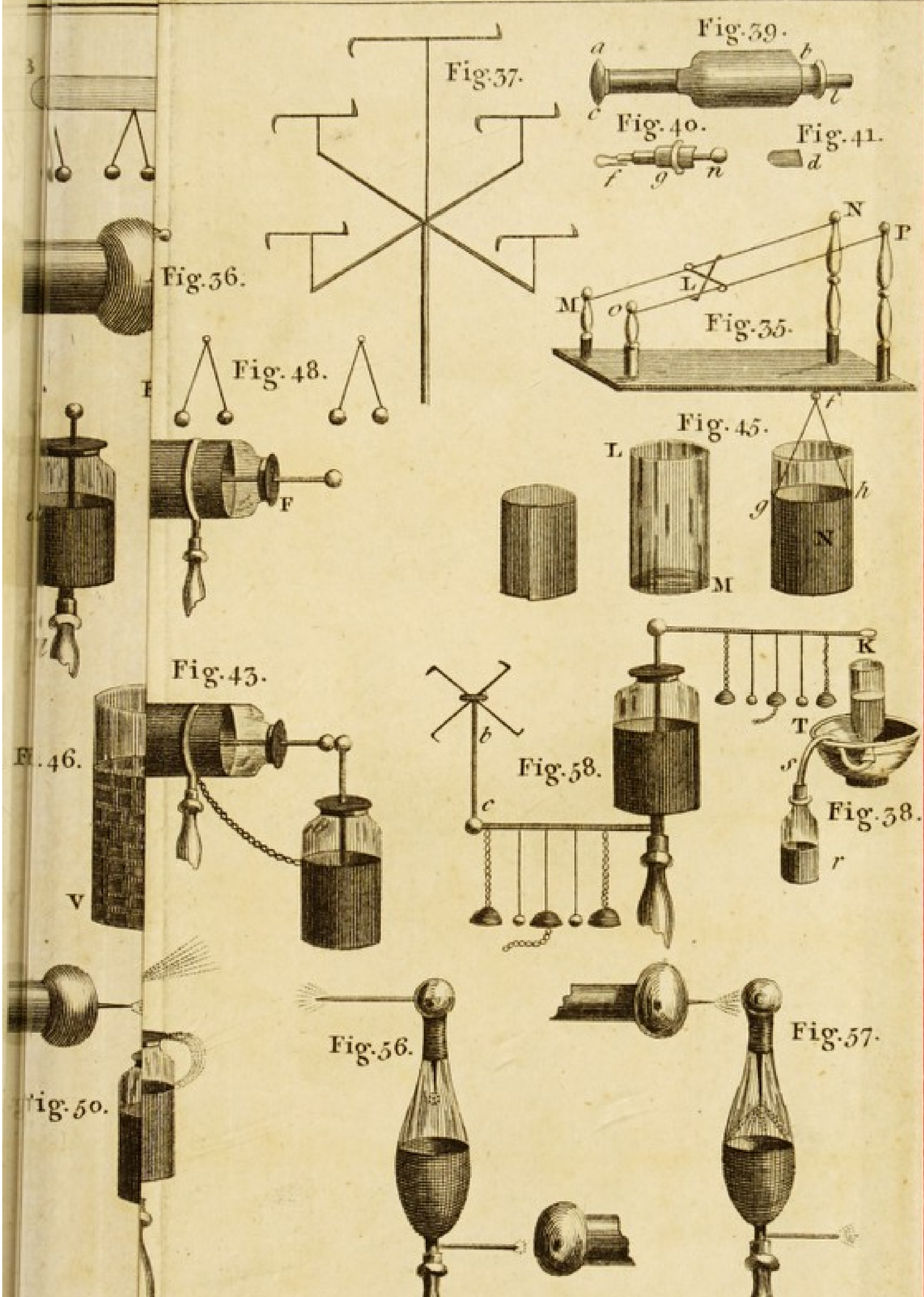

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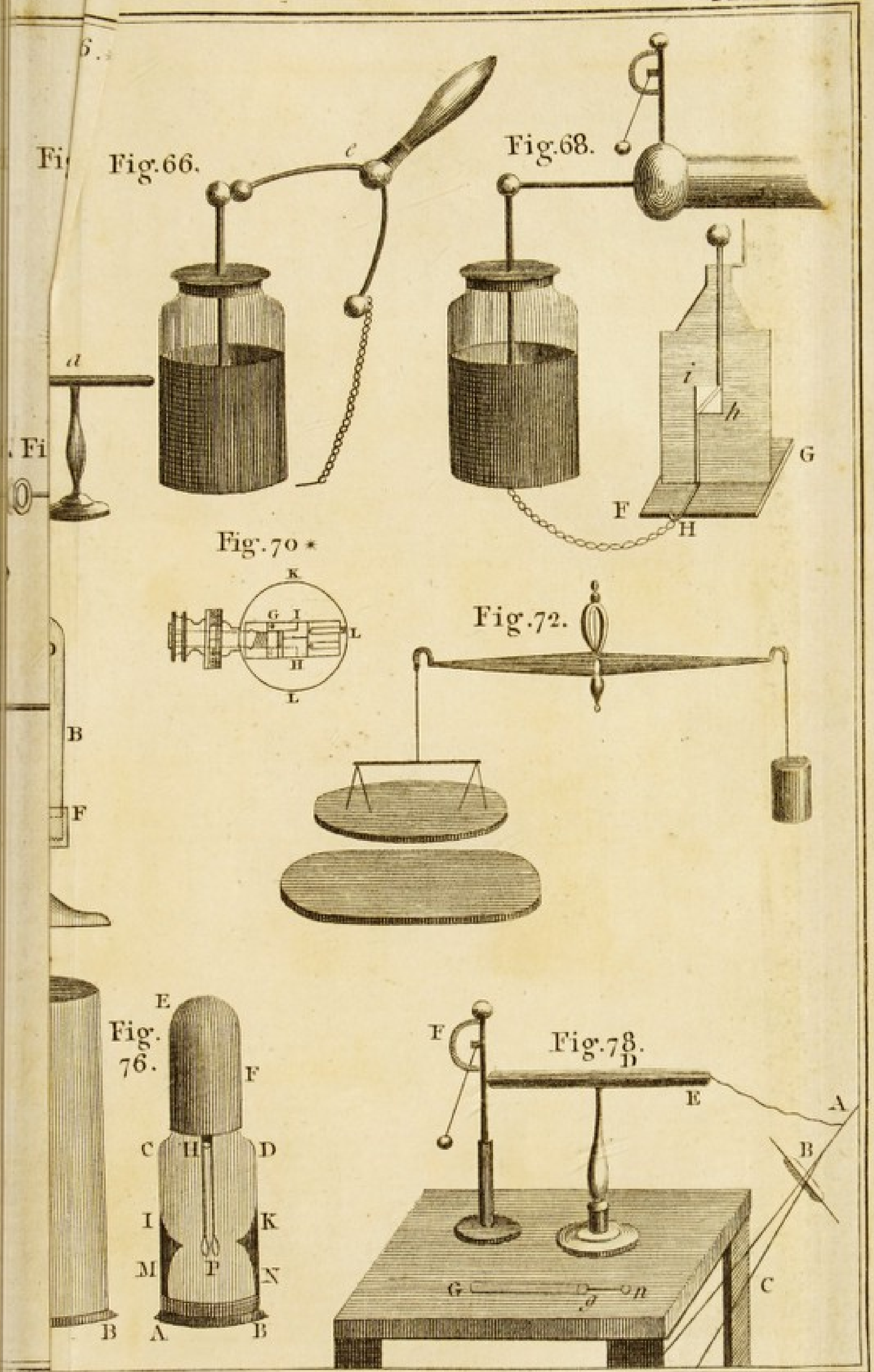

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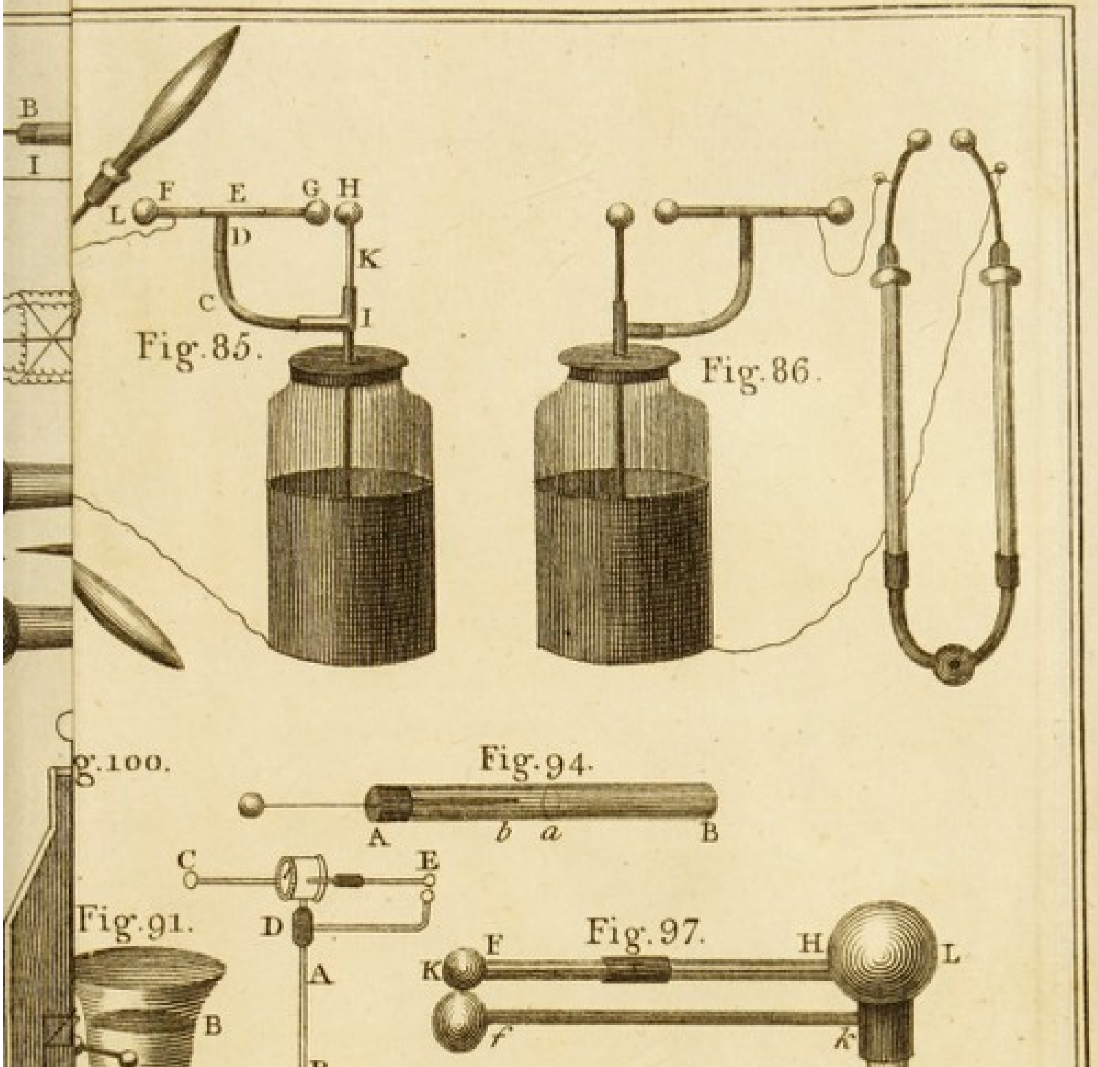

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A

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The $3\frac{1}{2}$ feet ditto, ditto, mahogany tube	17	6	6
Ditto, ditto, brass tube	19	8	6
Ditto all in brass, with rack-work motions, &c.	24	3	0
Achromatic perspective glasses for the pocket, in brass, &c. tubes, with a change of eye-glasses, from 12s. to	3	3	0
New-improved ditto, answering the purpose of an opera glass, with a compass and helioscope for viewing the sun, from 1l. 3s. to	2	2	0
New-improved achromatic pocket telescope, which, by a small apparatus within its tubes, is readily converted into a compound microscope	3	13	6
An improved portable seven-inch achromatic telescope in brass, with a stand that packs up into the tube of the telescope, adapted for astronomical uses	3	13	6
Reflecting Telescopes, fitted up either upon the *Gregorian Newtonian*, or *Herschelian* principles, with improved wood or metal stands, and other apparatus, for making celestial observations in the most commodious and accurate manner.—The general prices are as follow:			
— Fifteen feet in length, the large metal fifteen inches in diameter, from 250l. to	500	0	0
— Twelve feet in length, fourteen inch metal	200	0	0
— Ten feet in length, twelve inch metal	150	0	0
— Eight feet in length, eleven inch metal	140	0	0
— Six feet in length, nine inch metal	100	0	0
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Those reflectors that are constructed upon the principles of Newton *or* Herschel *are about twice the above lengths in the tubes. The reflectors upon the usual Gregorian construction are made with the vertical motion upon a new principle, so as to render them more firm and steady while in use, than any reflectors mounted in the common manner.*

	£.	s.	d.
A four feet seven-inch aperture Gregorian reflector, with the vertical motion upon a new-invented principle, as well as apparatus to render the tube more steady in observation; according to the additional apparatus of small speculums, eye-pieces, micrometers, &c. from 80*l.* to	100	0	0
Three feet long, mounted on a brass stand, common mounting	23	2	0
Ditto with rack-work motions, improved mounting, and metals	36	15	0
Two feet long, without rack-work, and with four magnifying powers, improved, 13*l.* 13*s.* to	14	14	0
Ditto improved, with rack-work motions	22	1	0
Eighteen inch on a plain stand	8	8	0
Twelve inch ditto	5	5	0
Telescopes, both refracting and reflecting, fitted up with equatorial, &c. motions, micrometers, adjusting, compensating, &c. apparatus, for the most accurate astronomical purposes			
Common MICROSCOPES, from 2*s.* 6*d.* to	1	1	0
Wilson's single pocket microscopes, from 18*s.* to	2	12	6
Compound microscopes improved, from 2*l.* 12*s.* 6*d.* to	5	5	0
New improved universal ditto	6	6	0
Ditto with the most complete apparatus	10	10	0
Solar microscopes in brass, improved, from 4*l.* 14*s.* 6*d.* to	6	6	0
The new opake and transparent solar microscopes, with improved apparatus, from 10*l.* 10*s.* to	16	16	0
Ditto of a larger size, with additional megalascopic apparatus, from 14*l.* 14*s.* to	19	19	0
Ditto, and best compound ditto, packed together in one mahogany box	21	0	0
The LUCERNAL MICROSCOPE, as improved by *W. Jones*, exhibiting images of opake and transparent objects by night or day, in a manner singularly pleasing, brilliant, and distinct, with upwards of 100 objects, proper apparatus, patent lamp, &c.	16	16	0
Ditto combined with a solar, compound, &c. apparatus, forming the most perfect collection of microscopical apparatus	35	14	0
A portable optical apparatus, consisting of a scioptic ball and socket, a solar microscope, Wilson's microscope, a pocket compound microscope, a pocket telescope, and solar telescope, in mahogany and brass	3	13	6
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A new universal pocket ditto, adapted to all sorts of objects	1	6	0
Ditto with adjusting screw, speculums, &c.	2	10	0
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A new set of moveable painted sliders, shewing the fundamental principles of astronomy, with the real and appa-

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For a description of this instrument, as well as of spectacles, reading-glasses, &c. see the late Mr. G. ADAMS's Essay on Vision, *8vo. price 3s. now sold by* W. *and* S. JONES.

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Concave and convex glass mirrors, in plain black frames, four, five, six, and seven inches diameter, each *9s. 12s. 14s.* and	0	18	0
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Nine inches ditto	1	7	0
Ten inches ditto	1	12	0
Twelve inches ditto	2	5	0
Fifteen inches ditto	3	13	6
Eighteen inches ditto	6	6	0
Twenty-one inches ditto	11	11	0
Twenty-four inches ditto	16	16	0
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	£.	s.	d.
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A brass cylindrical ditto, with a staff	0	18	0
Ditto with compass, agate capped needle, &c.	1	11	6
Improved ditto, with rack-work and pinion, and moveable divided limb, making a very portable cross-staff, compass, and theodolite, in one small instrument	2	18	0
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Sets of protracting and plotting scales; instruments for dividing lines, or transferring divisions on paper. An instrument for describing circles from four to six inches radius

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Sciatica Spark Shocks & vibrations
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Sore throat small shocks thro' —
Swellings various from obstructions & other
= wise
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which the tendons were variously
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shrunk or lost
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Hemiplegia
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