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.

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TO WHICH IS NOW ADDED,

A LETTER TO THE AUTHOR,

FROM

MR. JOHN BIRCH, *Surgeon,*

ON THE SUBJECT OF

MEDICAL ELECTRICITY.

The FOURTH EDITION.

By GEORGE ADAMS,

Mathematical Inſtrument Maker to His Majeſty, and Optician to His Royal Highneſs the Prince of Wales.

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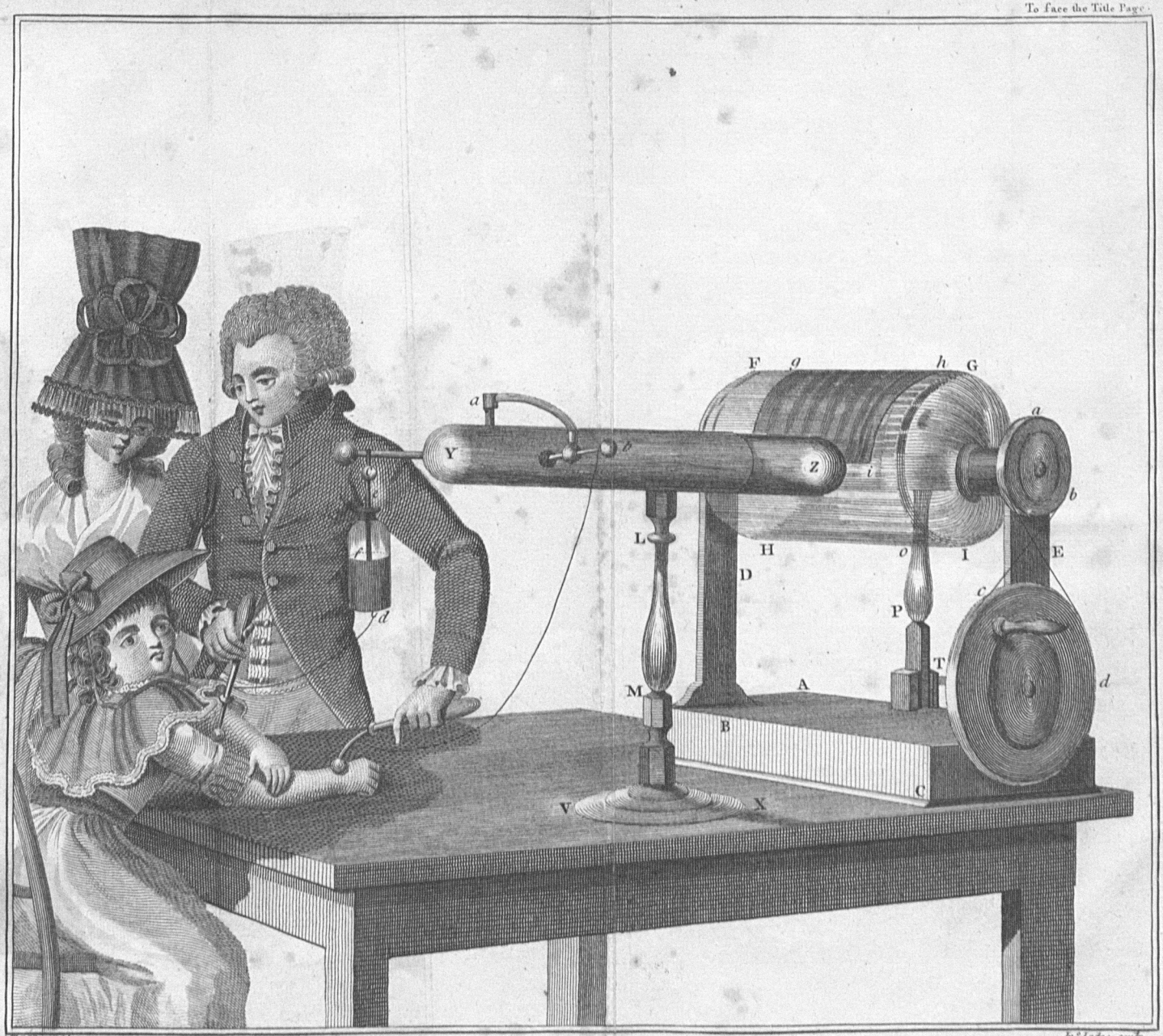

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PREFACE.

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. It's utility to man will not be inferior to it's dignity as a ſcience.

I have not attempted to trace electricity from it's firſt rude beginnings, or to follow the mind of man in it's 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 connection, 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 it's 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

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

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 phial.

TABLE

TABLE OF CONTENTS.

CHAP.		PAGE.
I.	A Summary View of Electricity, &c. —— ——	1
II.	Of the Diſtinction between Electrics and Non-Electrics, and of the Analogy between Electricity and Fire	32
III.	Of the Electrical Machine; with Directions for exciting it —	59
IV.	Of the Franklinian Hypotheſis.—Objections thereto.—Of Eeles's Syſtem ———	90
V.	Of the Electrical Apparatus	137
VI.	Entertaining Experiments by the Attraction and Repulſion of light Bodies ———	157
VII.	The Properties of Electric Attraction and Repulſion —	169
VIII.	Of the Electric Spark —	191
IX.	Of Electrified Points ——	215
X.	Of the Leyden Phial —	230
XI.	Of the Electrical Battery —	269
XII.	Of the Diffuſion and Subdiviſion of Fluids by Electricity —	288

XIII.

CHAP.		PAGE.
XIII.	Of the Electric Light in Vacuo	294
XIV.	Of the Influence of Pointed Conductors for Buildings —	323
XV.	Of charging a Plate of Air	355
XVI.	Of the Electrophorus, &c.	361
XVII.	Of Volta's Condensing Plates	373
XVIII.	Of small Quantities of Electricity, and the Methods of discovering them ——	396
XIX.	Of Atmospherical Electricity	422
XX.	Of Medical Electricity —	493
	A Letter from Mr. John Birch, Surgeon, on the Subject of Medical Electricity —	519

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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, of 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 manifeſted to our ſenſes by what are termed electric appearances.

 Theſe

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

Experiment.—Take a glaſs tube of an inch and a 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 ſilk, and it will exhibit electric appearances, or be excited. The power thus brought into action will attract and then repel ſmall light bodies; ſmall pencils of light will alſo dart from the tube in a beautiful manner, attended with a crackling noiſe, if the finger, or any other metallic ſubſtance, is brought near the tube.

Experiment.—Put your cylinder in good order, by the rules laid down in this work. Then turn the glaſs 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 more viſible in the former. In theſe two experiments the friction againſt the tube or cylinder has brought into action and rendered ſenſible an agent, which before was apparently dormant and inviſible to us.

With

With respect to the electric matter, all substances may be 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.—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.

This

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 it's 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

tricity is carried off by the communication. Whereas under the ſame circumſtances an excited electric loſes it's electricity only in thoſe parts, which are near the conducting ſubſtance, or to which it is applied.

EXPERIMENT.—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.—The 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 given in this work.

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

EXPERIMENT.—In working the electrical machine, this fluid is excited by friction. The Tourmalin ſtone is excited by increaſing or diminiſhing it's 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.—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.—Take off the chain, which is generally ſuſpended from the cuſhion to the table; turn the machine, and you will find leſs electricity than when the cuſhion or rubber communicated, by the chain, with the earth.

If

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.—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; and 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 re-consider 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

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, 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, ſometimes vitreous.

The

* Hence every electrical machine, with an inſulated rubber, may be conſidered as acting in a threefold 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.

The electricity produced by the excitation of ſealing-wax, or roſin, is called negative, or roſinous.

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

Experiment.—Electrify a pair of inſulated pith balls negatively, and they will repel each other.

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

Experiment.—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.

Expe-

EXPERIMENT.---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.---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.---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 phænomena of nature are carried on by these powers when united*, and the

the more particular phænomena, 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.—Light feathers, hair, &c. connected with the conductor, are, when electrified, attracted by any non-electric body.

EXPERIMENT.—The hair of any person that is electrified becomes repellent.

EXPERIMENT.—Downy feathers, bits of leaf gold, paper images, and other light bodies brought near the conductor, are first attracted, and then repelled.

EXPERIMENT.—The two outside bells, fig. 17, communicate by a chain with the conductor; the middle bell and the two clappers are suspended by silk, which is a non-conductor. 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 chain to the earth.

The

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.—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 electic fluid appears as a diverging ſtream darting forwards into the air from a pointed body poſitively electrified.

It

It appears as a little globular ſtar on a point negatively electrified.

EXPERIMENT.—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.—Theſe phænomena are beautifully exhibited by the luminous conductor.

A current of air is occaſioned from an electrified point.

EXPERIMENT.—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.—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

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.—Place a pointed wire on the end of a ſpiral tube, 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 tinfoil or any other conducting ſubſtance, is called the Leyden jar or phial.

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)

ſtance) 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 fig. 49, plate II. is the moſt ready, and beſt adapted for illuſtrating the phænomena of the Leyden phial, we ſhall confine ourſelves principally to it in this part of the preſent Summary.

Experiment.—Screw the phial with the belt on it's inſulated ſtand, as at 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.—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

will be heard, and the bottle will be difcharged; for in this cafe, the infulation of the infide is deftroyed by the chain, and the phial becomes capable of receiving a charge.

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

EXPERIMENT.—Place the coating of the jar, fig. 48, in contact with the conductor, and the knob of another equal fized jar (as L, fig. 49,) in contact with the knob of the firft; turn the machine a few times, then remove the jars from each other, and from the conductor; apply a difcharger, as before directed, firft to the one, then to the other, and you will find them both equally charged; the infide of the fecond phial having received from the infide of the firft, as much of the fluid as the outfide thereof received from the machine.

When a Leyden phial is charged, the two fides thereof are in contrary ftates; that is, the one is pofitively, the other negatively electrified.

EXPERIMENT.—Charge the jar, fig. 48, by bringing the coating in contact with the con-

 ductor,

ductor, 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.—Charge the jar, fig. 48, positively; connect a director with the chain from the coating, and bring the ball of the director towards the knob of the bottle; 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

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

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

EXPERIMENT.—Take two bottles of the ſame ſize, as H and I, 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 bottles will not be diſcharged; becauſe the inſide and outſide of each bottle 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.—Charge one poſitively, the other negatively; then on bringing the knobs together as before, an exploſion will take place, and both bottles will be diſcharged; in this the powers on the inſide and outſide of each bottle were of different kinds, with a ſtrong tendency to unite.

In

* 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 un-inſulated, be immediately carried to the earth.

In the foregoing experiments it will be found very convenient for the diſcharge of the jars, to ſcrew the wire K or L into the hole at the top of the inſulating pillar; as the coating of the moveable jar may be placed on this wire, and it's 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.—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 plates, and place it between two other plates of metal unelectrified and inſulated, and the plate of glaſs thus coated afreſh will ſtill be charged.

The

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.—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 placed in the circuit of communication.

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

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

EXPERIMENT.—If the circuit be interrupted by ſeveral folds of paper, a perforation will be made through it, and each of the leaves will be

* Enfield's Inſtitutes of Natural Philoſophy.

protruded by the ſtroke from the middle towards the outward leaves.

EXPERIMENT.—If ſpirits 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 inſide of a number of coated glaſs jars, and another communication between the external coating; jars ſo diſpoſed are called an electrical battery.

Fine

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 it's courſe the beſt conductors, ſets fire to bodies, melts metals; in which, and many other particulars, it agrees with the phænomena 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 hori-

zontal 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 it's 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 it's ball above the board, and it's 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 it's 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

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 phænomena, are the consequence of the air being thus charged. Thus the prime conductor imparts it's 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

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 it's effects as any medicine in the whole materia medica, and more extenſive in it's 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

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

This is always beſt effected 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 it's ſtead.

In the friction, the part ſhould be covered with woollen 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

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

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.

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 it's 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,

ſerence, 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.

Of a Vacuum.

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

As

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

EXPERIMENT.— Let a jar be charged in vacuo.

CHAP.

CHAP. II.

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

IT must appear surprising to every searcher after truth, that electricity, which is now allowed to be one of the principal agents employed in producing the phænomena of nature, should have remained so long in obscurity; for, comparatively speaking, it's 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 phænomena 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 emanci-

emancipated from the chains of hypothetic reasoning, and the uncertainties of vague conjecture.

The existence of this subtle, and in most cases invisible power was then traced, and many of it's properties developed; it's agency was discovered to be universal, and it's 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 phænomena 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 bit 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 swim-

ming 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 phænomenon, 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,

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 it's 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 connection."

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 it's infancy, when conſidered as a ſcience, it's definitions and axioms cannot be ſtated with geometric accuracy. I ſhall

endeavour to avoid, as much as poſſible, the uſe of poſitive expreſſion, 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 placed, 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

tracts 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; 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 it's 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 silk 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 silk 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

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 it's phænomena would have remained unknown to us; but, as it paſſes readily only over the ſurface of ſome ſubſtances, while others reſiſt it's 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 third and fourth 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 it's 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 it's 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

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

A large

* See Dr. Priestley's History. Cavallo on Electricity. Marât, Recherches sur l'Electricité.

A large piece of white ſpar, with a tinge of blue and ſemi-tranſparent, will hardly conduct in the leaſt degree: pretty 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 it's ſubſtance; though it will paſs over about three quarters of an inch of it's 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 on, is a much better conductor than a piece of free-ſtone, which conducts but poorly.

Touch-ſtone conducts pretty 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 it's 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*

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 it's 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 allum; the electric ſpark upon it is peculiarly red.

Sal-ammoniac exceeds rock-ſalt and allum in it's 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 poorly.

By allum 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,

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 pretty 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

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

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.

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,

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

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.
Rough glaſs	Positive	Dry oiled ſilk, ſulphur, metals.
	Negative	Woollen 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.

* i. e. 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.

Black

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, woollen 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 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 ballance 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

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.

What is Electricity?

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 it's preſence: it's ſmell is ſtrongly phoſphoreal or ſulphureous. The ſenſe of feeling is a witneſs of it's 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 it's 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;

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 it's reſervoir or fountain, and proceeds from it in the form of light. The culinary is that fire which is kindled upon earth by artificial means, and burns in any ſort of fuel. The elementary, is that ſubtil fluid which reſides conſtantly in all groſs bodies, and is not neceſſarily diſtinguiſhed by it's heat as culinary fire, by it's 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 gunpowder, 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 it's 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. Achard made the experiment on a dog when asleep, and always found, that the number of pulsations was increased when the animal was electrified.

The experiment made by Mr. Achard on the eggs of a hen, and by others on the eggs of moths, proves that electricity, as well as heat, favours the developement of those animals. The electric

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

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 sub-

ſtances, 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 a half diameter, with ſtems or tubes, about eight

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 the electric fluid on a thermometer.* Inſulate a ſenſible

ſible mercurial thermometer, and place the bulb between 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 a 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.

CHAP.

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 it's 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 the electrician.

1. The

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 it's appendages.

4. The conductor or conductors.

Fig. 8, plate I, 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 cylinder of the machine, in the frontiſpiece, is turned round by means of the two wheels a b, c d, which act on each other by a catgut band.

The cylinder of the machine, which is repreſented in fig. 8, is put in motion by a ſimple winch, which is leſs complicated than the multiplying wheel, and therefore not ſo liable to be out of order.* 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

* It is eaſier to manage, and may, in proportion to it's ſize, be more powerfully excited than thoſe with a multiplying wheel.

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.*

As the two machines, which are repreſented in the plates, are nearly ſimilar, the ſame letters of reference are uſed in deſcribing them.

A B C repreſent the bottom board of the machine.

D and E, the two perpendicular ſupports, which ſuſtain or carry the glaſs cylinder F G H I.

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.

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 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

* It may be proper to remark, that thoſe with a ſimple winch are cheaper than thoſe with a multiplying wheel.

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 is fixed on a ſliding-board.

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 conductor, or that which takes the electric fluid 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.

Directions for keeping the Machine in Order.

Before the electrical machine is put in motion, examine thoſe parts which are liable to

wear

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 be occaſionally applied to the axis of the cylinder.

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 on 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 it will be proper to dry 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, it's frame, the conductors,

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; these pillars must be rubbed more lightly than the cylinder, because they are varnished.

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

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,

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

2d, Apply the amalgam only to those parts.

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

4th, 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 it's 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 universaly 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

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 amalgamated leather, that part of the oil, 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 amalgamated leather, or by occasionally altering the pressure of 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 the cylinder with a clean cloth.

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* This observation is thought useless by many practical electricians.

EXPERIMENT IX.—When the cylinder is put into good action, a number of circular lines of 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 it's 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

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 quantity 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 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 ſurperfluous 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.

EXPERIMENT X.—*On the effect 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 laſt 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 it's ſurface, and thence half round the cylinder. The cylinder was then excited by applying an amalgamed leather in the uſual manner. The electricity

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 the 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 interpoſi-

tion

tion 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 it's not having been ſufficiently ſupplied, during it's 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 it's 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

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

to a plate machine. One cuſhion was applied with it's ſilken flap. The plate was nine inches in diameter, 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 a 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.

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 it's correſpondent cuſhion, ſo that it's diſtance was leſs than between the thumb and it's 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 it's electricity till the rubbed ſurface had given out it's 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

the prefent methods of excitation feem capable of collecting; but that when the excitation is weak, on account of the electric matter not paffing with fufficient facility to the rubbed furface, the friction enables the oppofite furface to attract or receive it, and if it be fupplied, both furfaces will pafs off in the pofitive ftate; and either furface will give out more electricity than is really induced upon it, becaufe the electricity of the oppofite furface forms a charge. It may be neceffary to obferve, that we are fpeaking of the facts or effects produced by friction; but how the rubbing furfaces act upon each other to produce them, whether by attraction, or otherwife, is not here the fubject of inquiry.

It will hereafter be feen, 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 furface; which is a corroboration of the inference here made.

16. When a cylinder is weakly excited, the appearances mentioned (par. 8.) are more evident, the more rapid the turning. In this cafe, the avidity of the furface of the cylinder beneath the filk is partly fupplied from the edge of the filk which throws back a broad cafcade of fire, fometimes to the diftance of above twelve inches.

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 at 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

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 that 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

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. N. 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 excitation; yet as this buſineſs was originally performed by a cuſhion only, it

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 does on the other. Mr. N. 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. N. therefore applied the edge of the hand as a rubber, and by occasionally bringing forward the palm, he varied the quantity

* Philosophical Transactions, Vol. LVI. p. 117.

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. N. paſted a piece of leather upon a thin flat piece of wood, then amalgamed it's whole ſurface, and cut it's 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 it's edges rounded, and it's 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 re-

gulate it's 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 it's intenſity, prevents it's 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 would 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 form the edge of light.

22. Mr. N. hopes the conſiderable intenſity he ſpeaks of will be an apology for deſcribing the manner in which it was produced, wiſhing the

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 it's 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 it's 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 7 inches diameter, and cuſhion 8 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 1½ inch diameter

meter 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 4 inches diameter: with a ball of $2\frac{1}{2}$ inches diameter the flaſhes ceaſed now and then, and it began to appear luminous: a ball of $1\frac{1}{2}$ inch diameter firſt gave the uſual flaſhes; then, by quicker turning, it became luminous with a bright ſpeck moving about on it's 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 it's 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 phænomenon is ſimilar to a natural event related by M. Loammi Baldwin,* who

 raiſed

* Memoirs of the American Academy, vol. 1. p. 257.

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 ſurpriſed 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 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

With a 12-inch cylinder, and rubber of 7¼ inches, a five-inch ball gave frequent flashes, upwards of 14 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 7-inch cylinder affords a spark of 10¾ inches at best. The 9-inch cylinder, not having it's conductor insulated on a support sufficiently high, afforded flashes to the table which was 14 inches distant. And the 12-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 that 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 2½ 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 it's 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 would cauſe a cylinder to charge one ſquare foot by the friction of 33½ ſquare feet. It muſt be obſerved, however, that M. Van Marum's own machine, conſiſting of two plates, 33 inches diameter, has only half the intenſity, though he reckons it a very good one. This machine is

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

is about equal in abſolute power to my 9-inch cylinder, with it's 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 it's 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 moiſtening 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.

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 it's 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,

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 ſearch 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

are liable to be controverted, we are obliged to ſeek for demonſtrative proof, by adverting to practical inveſtigation.*

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 hypotheſes: 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 æther 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

* Tatham's Sale and Chart of Truth.

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 phænomena which they obſerved to ariſe from the excitation of ſuch ſubſtances. To theſe hypotheſes may be added the ingenious Abbé Nollet's doctrine of electrical affluences and effluencies, 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

all electrical phænomena 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 it's 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 it's natural state it's effects are invisible, and we are totally insensible of it's power; but whenever the equilibrium is disturbed, we are immediately sensible of it's 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 it's appearance, nor have become in any measure sensible of it's effects; but, because some substances freely admit of it's

passage

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

* Becket's Eſſay on Electricity.

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,

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 it's 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 elec-*

tric 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 is 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

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 it's 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 it's 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 perſons on wax 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 wax 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 wax, his body is not again immediately ſupplied.

B, who alſo ſtands upon wax, 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

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 ſubtle 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 it's natural ſtate of the electric fluid, and negative electricity when it has leſs than it's natural ſhare.

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 connection 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. 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

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 phænomena 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 proof falls 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

the tube be ſuddenly removed, the tube 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 nearcſt 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 it's natural ſtate of electricity, or is electrified negatively.

It is obvious to remark, before ſuch conclu-ſion 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, the other too little elec-

 tricity?

tricity? 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

the Leyden phial. If Dr. Gray had considered Mr. Eeles's syſtem, it is probable 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.

Of Mr. Eeles's Hypothesis.

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

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

author many phænomena 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 phænomena but what are more readily accounted for on this ſyſtem, than 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 it's 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

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

the oppofite furface is electrified with the contrary power, *if it be not infulated.*

Either power being applied to one of the furfaces, attracts the contrary power through the fubftance of the electric, and repels the electricity of the fame fort with itfelf.

The two powers being brought to the oppofite furface of the plate which is impervious to them, remain fufpended, ftrongly attracting each other till the interpofed plate is broken by their force, or a communication is formed between the two furfaces by fome conducting fubftance.

The union of the two electricities deftroys the effects of each other, and leaves the plate difcharged.

If either furface of a charged plate communicate with the earth, the power on the oppofite furface will expand itfelf into a conductor which is contiguous to it, although the conductor be infulated.

EXPERIMENT XIX. — Let one furface of a charged plate be infulated: although the other communicates with the earth, no difcharge of either furface will follow.

EXPERI-

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 12 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

ditional 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 of 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 farther. 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 which 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 by 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

ceiving 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 bottle 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 bottle by the outſide, and *a* excite the diſcharge by touching the knob of the bottle; 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 it's 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 gives 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 bottle, 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 it's own stream; one that enters the bottle, 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 it's own deficiency.

It appears also, from other experiments, that one side of a charged electric may contain more of

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

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

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 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 bottle 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

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 XXV.—Take a piece of bog-down,* ſuſpend it by ſilk; then take a pane of 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 it's 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 com-

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

munication from one ſide of the glaſs with 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

ing 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 3 or 4 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 phænomena. The two contrary

trary 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 powers of electricity into the glass.

Now the non-electric being taken away, the different powers in the glass are rendered unequal to each other; and the increased power, by it's 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

* 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. Eeles's opinions.

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 bottle, 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 bottle, ſuſpend the bottle by ſilk, and bring it ſo that the rod from the inſide may point to the conductor. While the 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 bottle over the conductor for the ſame time, with the wires from the bottom, pointing to the conductor, and you will find the bottle to be diſcharged. But let it remain

* See this clearly proved by Wilſon's Experiments.

main as long again, and the bottle 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 bottle, 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 bottle, 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 bottle, and thus the bottle remains charged when taken from the atmosphere of the conductor.

When the experiment is reversed by bringing the wires at the bottom of the bottle 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 bottle 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 it's 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 makes directly againſt the Franklinian ſyſtem, and in favor 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.

EXPE-

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 images will fix themselves to the lower plate. If the image retains so much more of the attracted power as will ballance against it's 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

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 5 or 6 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

vitreous power of the tube attracting part of the resinous power from the first glass, and adding part of it's 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 bottle upon an electric stand, and let a cork ball, suspended by silk, hang against the outside of the bottle; touch the top of the bottle, and the ball flies

flies off ſtrongly electrified with the reſinous power; and thus you may go on for a great number of times, to alter the balance within ſide and without ſide the bottle, 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 without ſide 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 power, or plus.

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 it's natural ſhare of that power*, can give another body an additional ſhare of that power; they 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 it's own elaſtic force, expand

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 bottle, so that the point may stand upright; and on that point place the needle with the reversed points. Place this bottle on an electric stand, with a communication from the conductor. All the time the bottle is charging, the needle will turn; but when the bottle 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 bottle is discharged. Now while the bottle is charging, if you touch the needle with a piece of bog-down, suspended by silk, you will find it electrified by the vitreous power, which flies off in exchange for the resinous power drawn in from the air to the outside of the bottle; and while the bottle 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 bottle in exchange for the vitreous power drawn in through the points from the air; while the vitreous power from the inside of the bottle makes the same exchange for

the refinous power through your finger, to make these different powers equal to each other, withinside and withoutside the bottle.

EXPERIMENT XXXIII. — Place two Leyden bottles 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 bottle with his finger; you will find the first bottle charged with the vitreous power inside, and the second with the refinous power inside. Now the exchange here is evident; for while the refinous power from the inside of the first bottle changes place with the vitreous thrown in from the conductor, the vitreous, from the coating, changes place for so much of the refinous from the coating of the second bottle; and the vitreous in that bottle changes place for so much of the refinous power drawn in through the man on the floor.

I could easily, says Mr. E. furnish experiments sufficient to fill a great deal of paper; but I shall only mention one or two which I 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

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. E. 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 Mr.

Dufay, and Mr. Symmer; he obſerves, that Mr. Dufay 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 Mr. Dufay'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 bottle, 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

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 So-

ciety; 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.

CHAP. V.

On the Method of using the Electrical Apparatus, and a Description of some 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 inſide 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

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.

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

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

the leather muſt not be removed until it ceaſes to become greater.

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 connection 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 this, three kinds of *diſcharging rods* have been contrived; one of theſe, repreſented fig. 1, pl. II. 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 junctiure 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, pl. II: the legs of this are moveable, and may

be ſet to any given diſtance by means of the joint *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 it's 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 it's ſurface, ſomething

thing 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

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

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 pricking 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 fig. 8, pl. II. 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

connected with it, are ſaid to be *negatively electrified.*

Of the Apparatus figured in the Plates.

Fig. 13, plate II. 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. 25, plate II. repreſents two wires, placed parallel to each other, for the ſame purpoſe; in this way, however, it is difficult to make the experiment ſucceed.

Fig. 17, plate II. is a *ſet of bells:* 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.

Fig. 18, plate II. 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, plate II. *a ſet of muſical bells.* 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 pillar e f, in which it turns with great freedom; bells of different tones are placed round the boards 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 this 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 effect.

Fig. 14, plate II. a braſs wire, with two cork balls ſuſpended thereto with ſilken threads.

Fig. 10, plate II. a ſimilar wire, with two downy feathers ſuſpended by linen threads.

Fig. 20, plate II. a bundle of thread tied together at each end.

Fig.

Fig. 12, plate II. 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. 22, 23, 24, 25, 26, 27, ſmall cylinders of wood or braſs tubes on inſulating ſtands, furniſhed with pith balls; four tubes and ſtands are generally enough. The experiments with this little apparatus are intereſting and inſtructive.

Fig. 3, plate II. repreſents the univerſal diſcharger; an inſtrument which is of very extenſive uſe in forming communications to direct or convey the electric ſhock through any part of a given ſubſtance. Many examples of the utility of this inſtrument will occur in the courſe of this Eſſay.

A B, fig. 3, is the baſe of the univerſal diſcharger; on this are fixed two perpendicular glaſs pillars C, D; on the top of each of theſe is cemented a braſs cap, to which is fixed a double joint, or one which has both a vertical and horizontal motion; on the top of each joint is a ſpring tube which receives the wires E T, E F; theſe wires may be ſet at various diſtances from each other, and turned in any direction; the extremities of the wires are pointed, the

points are covered occasionally by the brass balls, which are made to fit on the wires by spring sockets: G H is a small wooden table, on the surface of which a slip of ivory is inlaid; this table is furnished with a cylindrical stem, which fits into a cavity of the pillar I; it may be raised occasionally to various heights, and fixed at any one of them by the screw K.

Fig. 4, plate II. is a little wooden press, furnished with a stem, which fits the cavity in the pillar I, fig. 3, into which it is to be placed occasionally, when the table G H is removed. The press consists of two boards, which are brought close to each other by means of the screws a a.

Fig. 5, plate II. is Mr. Kinnersley's electrical air thermometer; a b is a glass tube, on each end of which a brass cap is cemented; c d is a small glass tube, open at both ends, which passes through the upper, and descends nearly to the under plate: a box scale, which is divided into inches and tenths of inches, is fitted to the upper part of this tube; g is a brass wire with a ball on it, which is screwed to the under plate; a similar wire f h is made to pass through a collar of leathers on the upper plate, and may be placed at any convenient distance from the lower wire.

Fig.

Fig. 1, plate II. a ſemicircular diſcharging rod.

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

Fig. 6, plate II. *a quadrant electrometer.*

Fig. 9, plate II. *Mr. Townſend's electrometer.* Theſe inſtruments will be deſcribed under the article electrometers.

Of the Apparatus figured in Plate III, IV, V.

Fig. 34, plate III. *the electrical flyer* conſiſts of two ſharp pointed wires, jointed 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, plate III. repreſents a ſimilar flyer, acting in a different poſition, the axis being at right angles to the flyer, with two ſmall pullies, one at the end of each axis; the wires M N, O P, ſhould be inſulated, and the inclination to the horizon very ſmall.

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

Fig. 37, plate III. a ſet of flyers.

Fig. 31, plate III. *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 ſtuck upon it's 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 ſtuck on flat pieces of glaſs, 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, plate III. 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. 98, plate V. *a ſet of ſpiral tubes* placed round a board; in the center of the board is an inſulated pillar, on the top of this is a braſs cap, carrying a ſmall ſteel point; a braſs wire furniſhed with a ball at each end, and nicely

balanced, is placed on the point. The middle of this wire ſhould receive the ſparks from the conductor, or a bent wire and ball affixed to the conductor.

Fig. 38, pl. III. the apparatus ſold at the glaſs-ſhops for making inflammable air.

Fig. 39, plate III. *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 into the end a c, to prevent the eſcape of the 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. 40, plate III. repreſents the part within the piſtol, by which the ſpark paſſes through and fires the inflammable air.

Fig. 49, plate III. 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; an 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. 42, 43, 44, 48, 50, 51, 52, 54, 55, 56, 57, plate III. 59, 60, 61, 62, plate IV. represent some of the various experiments which may be performed by the compound apparatus.

Fig. 45, plate III. represents a jar with *moveable coatings:* the innermost coating is to be taken out by the silk strings f, and the jar then lifted out from the external coating.

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

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

Fig. 53, plate III. the *belted bottle,* designed to prove the direction of the electrical fluid in the charging and discharging of the *Leyden phial.*

Fig. 58, plate III. the *Leyden bells:* an interesting apparatus, which affords much amusement, while it illustrates clearly the nature of the *Leyden phial.*

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

Fig.

Fig. 65, plate IV. represents a *battery* consisting of 9 jars.

Fig. 66, plate IV. an apparatus for rendering eggs luminous.

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

Fig. 73, plate IV. an electrical cannon.

Fig. 74, 75, plate IV. an electrophorus.

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

Fig. 78, plate IV. a conductor and electrometer connected with an electrical kite.

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

Fig. 84, 85, 86, 88, 93, 100, plate V. are different articles of a medico-electrical apparatus.

Fig. 85, plate V. 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, plate V. a *Leyden phial*, electrometer, and electrical forceps.

Fig. 100, plate V. a director and small bottle;

in the form of a director, for conveniently giving ſmall ſhocks.

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

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

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

Fig. 89, plate V. 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 of this model is fitted up like the thunder-houſe, 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

der will throw off the roof, and the ſides, the fore and back fronts will then all fall down.

Fig. 90, plate V. 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, plate V. 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 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 to 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

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 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 inflammable air-pistol, &c. It is also convenient to light a candle for œconomical 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

ſionally made, that affords conſiderable amuſement; as either one piſtol, or the whole together, may be fired at the pleaſure of the operator.

Fig. 92, plate V. 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. 94, plate V. a glaſs tube and wire, for making experiments on the conducting power of water.

Fig. 96, 97, plate V. Mr. Brooke's electrometer.

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

Fig. 100, plate I. electrical appearances from Mr. Bennet's work.

The many alterations that have been made in the plates of this work ſince the publication of the firſt edition, made in conſequence of improvements in the ſcience itſelf, have rendered it almoſt impoſſible to keep the numbers; but from the care taken, by giving an account of the different articles in this chapter, it is hoped that the reader will meet with no difficulties on this head.

Fig.

Fig. 1, 2, 3, 4, 5, 6, 7, plate I. electric appearances as described by Mr. Nicholson.

Fig. 8, plate I. an electrical machine with a simple winch.

Fig. 9, plate I. an *electrical doubler.*

Fig. 10, plate I. Mr. Bennet's electrometer.

Fig. 11, 12, 13, plate I. Mr. De Saussure's electrometer.

Fig. 14, 15, 16, 17, plate I. experiments on air.

Fig. 18, plate I. Mr. Bennet's apparatus for atmospherical experiments.

Fig. 19, 20, plate I. experiments with Mr. Bennet's electrometer.

Fig. 22, plate I. the spider-bottle.

CHAP.

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 A B, fig. 10, pl. II. 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

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 it's 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 it's 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 C D, fig. 11, pl. II. 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

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,

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, fig. 12, pl. II. 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.

EXPERI-

EXPERIMENT XXXVIII.—*Dancing images.* Suſpend the ſmall metal plate F, 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 it's 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 head 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 con- " ductor, 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 experi- " ment; 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

* Philoſophical Eſſays. Preface, page 25.

" the attracted power as will ballance against
" it's 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 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 it's atmoſphere, let it go; it will then fix itſelf to the conductor by the apex of it's obtuſe angle, and, from it's 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 it's ſtand I under it, and at a little diſtance from it, put a very light hollow glaſs

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 it's own axis: the poles of it's rotation are nearly at right angles to the plane of it's 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 ball, 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 different tones are placed round the board h I K. Remove the prime conductor, and place this apparatus in it's 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

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 it's 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 phænomena are occaſioned by the ſtate of the electric fluid*, in thoſe ſubſtances which are influenced by the machine.

EXPERIMENT XLVIII.—*Dancing balls.* Put a 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 pith 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.

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 it's strong attractive and repulsive powers. The phænomena 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 powers 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 n'est* "*pas*; sans aucun intermede? Deux particules de *matiere* "sont

far 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 it's transmission through them, with the greatest velocity; and this in proportion to the gravity of the body, it's conducting power, and the state of the air.

2. Bodies that are electrified positively repel each other.

3. Bodies electrified negatively repel each other.

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

5. Bodies

" sont à cent milles lieues, ou à cent milliemes parties d'un " ligne de distance l'un de l' autre, sans aucune communi- " cation materielle entrelles, et à l'occasion de l'une l' autre " se mouvroit!!" De Luc, Lettres Physiques, &c.

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 attentive examination, they will be found of considerable importance, as they afford a clue to investigate and explain a variety of electric phænomena, 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 brass tubes, as A and B, fig. 22; each of these is supported on a glass pillar G, which screws into a wooden foot H; a pair of small

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 phænomena 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 it's 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

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.

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 it's 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 it's 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

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 this 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 un-electrified; 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.

EXPERI-

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 ſtrait 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,

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. 23, 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

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 ballance the loſs ſuſtained, the tube, thread, and balls muſt be in a negative ſtate.*

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

N contained

* Wilſon's Short View of Electricity, p. 7.
† Ibid. p. 8.

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, fig. 28, plate III. 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 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

* Ibid. p. 8.

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.

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

* Ibid. p. 18.

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 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 phænomena, which depend on the influence of the electric atmoſpheres, may be produced, although an electric is interpoſed between the body and excited electric.

The

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 the work.

To account for any of the phænomena 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 be neither augmented nor diminiſhed on the ſurface of that 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,

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

mised, 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 to repel each other."

"The

" * 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."

" † 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

* Encyclopædia Britannica, p. 2683.
† Ibid. p. 2699.

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.

"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 ſurround-

ing

ing 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 it's 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 it's braſs cap; this was then electrified; the balls diverged a little when the air was only rarified 100 times; when it was rarified 300 times, the repulſion was ſcarce diſcernable: when the rariſaction was greater, they did not diverge

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 Ribbon.

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 them; while they continue on the plane they do not ſeem to have acquired any electricity, yet when

* Phil. Tranſ. vol. 70, p. 452.

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,

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,

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

parated again, their electric virtue does not seem to be 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 17 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 a 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.

CHAP. VIII.

Of the Electric Spark.

Experiment LXXIV.

FIX the wire and ball B to the end of the conductor, as at A, fig. 29, pl. III. 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 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

ſmaller diſtance, which, as it were, entices the diſcharge gradually forwards.

The longeſt and moſt denſe ſparks proceed from that 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 ſtrait; but when it is ſtrong, and capable of ſtriking at a greater diſtance, it aſſumes a crooked or zig-zag direction;

tion; and this, probably, becauſe the more fluid electric matter has to paſs with great rapidity through the denſer and leſs fluid atmoſphere, which reciprocally act 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 it's electricity; *a large divergent cone*, if poſitive; *a ſmall*

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 it's 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 it's denſity, and the thickneſs of the ſtratum it oppoſes to the ſpark, or the length of the paſſage they open for themſelves through it's 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 it's particles, but to the mutual action of the air and electric fluid upon themſelves and one another; and that it's momentum is produced by the incumbent

cumbent 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 it's denſity: when it is rare, it appears of a blueiſh 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 it's entrance and exit.

The ſpark is ſometimes divided into many parts, as in fig. 30, pl. III. 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 bottle 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 which 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

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 ſubtle medium both in electric and non-electric bodies, that renders them tranſparent, when it is put in motion?

EXPERIMENT LXXX. — *Green ſparks.* The ſparks taken over a piece of ſilver leather, appear of a green colour.

EXPERIMENT LXXXI. — *With the ſpiral tube.* E, F, 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

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 it's 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 word in characters 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 dis-

charge 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 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

brilliancy of the light and it's 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 sallad 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,

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 it's 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 it's 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

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 however be taken to hold the directors at a little

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 it's 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

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,

ing, 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 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 woollen, 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, fig. 33, then pour a ſmall quantity of ſpirits of wine into it, and fix it by it's handle to the end of the prime conductor; or fire the ſpirits, and blow them out a few minutes before the experiment

is

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 inſulating 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

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 of procuring it: put ſome ſmall nails or iron filings into the bottle r, 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.

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 15 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 intirely 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

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 it's 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 piſtol 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 it's 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 it's 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 it's 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 bottle, 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.

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 air. 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 it's 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

* Cavallo on Air, p. 818.

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.

CHAP.

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 it's phænomena, 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. There-

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 at 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 it's 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.

EXPERI-

* Encyclopædia Britannica, p. 2699.

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 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, fig. 34, upon the point, the ends of which cross are all bent one way; electrify the conductor, and the cross will turn upon it's 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.

EXPERI-

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

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 is kept out of ſight. But a more ſtriking ſight, would be a number of theſe boats, with each of them a twirling fly, about an inch in length, fixt to the top of the maſt; the hand held over them would ſet them all in motion; in

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 hang 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

* Becket's Eſſay on Electricity, p. 36.

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 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 it's 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 ſtrait 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

When two equal balls were prefented to each other, and one of them was rendered ftrongly pofitive, while the other remained in connection with the earth, the pofitive brufh or ramified fpark was feen to pafs from the electrified ball; when the other ball was electrified negatively, and the ball, which before had been pofitive, was connected with the ground, the electricity (paffing the fame way, according to Franklin) exhibited the negative flame, or denfe ftrait and more luminous fpark, from the negative ball; and when the one ball was electrified *plus*, and the other *minus*, the figns of both electricities appeared. If the interval was not too great, the long zig-zag fpark of the *plus* ball, ftruck to the ftrait flame of the *minus* ball, ufually at the diftance of about one-third of the length of the latter from it's point, rendering the other two-thirds very bright. Sometimes, however, the pofitive fpark ftruck the ball at a diftance from the negative flame. Thefe effects are repreferted in plate I. fig. 1, 2, 3.

Two conductors of three-quarters of an inch diameter, with fpherical ends of the fame diameter, were laid parallel to each other, at the diftance of about two inches, in fuch a manner as that the ends pointed in oppofite directions, and were fix or eight inches afunder. Thefe, which

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 it's 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 it's 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

greateſt when they ſtand remote from other ſurfaces in the ſame ſtate; and that between this greateſt diſpoſition in any ball, whatever may be it's diameter, every poſſible leſs degree may be obtained by withdrawing the ball towards the broader or leſs convex ſurface, out of which it's 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 it's axis in either direction, it cauſes the fine point either to protrude through a ſmall hole in it's 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 whatever, from the minuteſt

ſize to the diameter of ſix inches. See fig. 7, let. 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 it's 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

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 it's 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 it's 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 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

* Introduction to Natural Philosophy, Vol. II. p. 320.

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.

CHAP. X.

Of the Leyden Phial.

THE experiments upon the Leyden phial 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 phial.* 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 bottle will in a little time be charged, or modify the electric fluid in a peculiar manner. To diſcharge the jar, or reſtore it to it's natural ſtate, bring one end of a conducting ſubſtance 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, and the report very loud.

Experiment cx.—*The electric ſhock.* Charge the Leyden bottle, then touch the outſide coating

ing with one hand, and the knob with the other, the bottle 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 bottle 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 phial 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

hole will be pulverized, and very often a variety of fiſſures will proceed from it in various directions.

A Leyden jar very often recovers it's 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 the Leyden phial 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 ſubtle 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 an exploſion, when

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 they will receive a ſhock, and generally fail in the attempt.

Dr. Franklin's Theory of the Leyden Bottle.

Glaſs is ſuppoſed to contain at all times, on it's 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 bottle, 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 it's place and ſituation; i. e. we may throw an additional quantity on one of it's 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 it's 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 it's 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,

face, 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 bottle 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 it's 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 it's 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 it's 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 it's 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 it's original state of equality on the two sides of the glass.

THE

THE LEYDEN PHIAL 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

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 it's electricity, but only has it's fluid changed; and when the fluids are separated, they are ever eager to conjoin again.*

Combined Apparatus.

The apparatus, represented fig. 49, will be found exceedingly convenient for making a variety of experiments on the Leyden phial. I have endeavoured to combine the parts of it in in such manner, as to render the apparatus extensively useful, without being complicated. A, is an insulated pillar of glass, which is screwed to

* See Eeles's Philosophical Essays; Wilson's Short View of Electricity; and Milner's Observations on Electricity,

to the wooden foot B: all the different parts of the apparatus may be ſcrewed alternately on this pillar. C, is an exhauſted tube of glaſs, furniſhed at each end with braſs caps: 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 of the Leyden vacuum, or the plate 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 ſhoulder a b, c d, then work the ſyringe, and in a few minutes the glaſſes will be ſufficiently exhauſted. H and I are two Leyden bottles, each

 of

of which has a female screw fitted to the bottom, in order that they may be conveniently screwed on the pillar A. The bottle H is furnished with a 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 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 it's 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,

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 it's 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, fig. 42, on the inſulated pillar d, and bring it's knob in contact with the conductor; hold another bottle c, of the ſame ſize with a, ſo that it's knob may be in contact with the outſide coating of the bottle a; turn the cylinder, and when the bottle a is charged, place c on the table, then unſcrew a from it's 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 ſilk ſtring, ſo that the braſs ball may touch

the knob of the bottle; obſerve at what height the index of the electrometer ſtands, and then remove it to the other bottle, which will raiſe the index to the ſame height; *ſhewing clearly, that the bottle has thrown off from the outſide as much electricity as it received on the inſide.*

EXPERIMENT CXIV.—*Bottle charged by the action of the two powers.* Place the knob of an inſulated bottle in contact with a poſitive conductor, and connect the outer coating with the cuſhion, or a negative conductor, turn the cylinder, and the bottle will be charged with it's own electricity; the fluid from the exterior coating being transferred to the interior one; the bottle is charged in this inſtance without any communication with the earth.

EXPERIMENT CXV.—Charge the two bottles, 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 bottles will not be diſcharged, becauſe neither ſide has any thing to communicate to the other.

EXPERIMENT CXVI.—*Exploſion through flame.* Charge the inſulated bottle, 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 bottles will be

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 bottle, and charge it negatively; when it has received a full charge, the index will stand at 90 degrees; then place the bottle with it's electrometer at the positive conductor, turn the cylinder, the electrometer will descend, and the bottle will be discharged by the contrary electricity.

EXPERIMENT CXVIII.—Insulate two Leyden bottles; 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 silk strings f, g, h; the jar may be taken from it's 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 bottle.* T V, fig. 46, repreſents a bottle, whoſe exterior coating is formed of ſmall pieces of tin-foil, placed at a little diſtance from each other. Charge this bottle 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 viſible. Diſcharge this bottle, by bringing a pointed wire gradually near the knob, and the uncoated part of the glaſs 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. To produce theſe appearances, the glaſs muſt be very dry.

EXPERIMENT CXXI.—String a parcel of ſhot on a ſilk ſtring, leaving a ſmall ſpace between each of them; ſuſpend this from the conductor, ſo that it may reach the bottom of a coated phial, 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

between each of the ſhot, both within and without the bottle, as if the fire paſſed through the glaſs.

EXPERIMENT CXXII.—Hold a phial in the hand which has no coating on the outſide, and preſent it's 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 bottle, 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 bottle.* Fig. 47 repreſents two Leyden phials, placed one over the other. Various experiments may be made with this double bottle, which are very pleaſing, and elucidate clearly the received theory.

Bring the outſide coating of the bottle A in contact with the prime conductor, and turn the machine till the bottle 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 it's 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 it's 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 it's 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 dis-

charge

charge 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 bottle, B the under bottle.

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 discharge.	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 com-

municating 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 diſcharge.	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 BOTTLE, SHEWN BY THEIR RESPECTIVE ATTRACTIVE AND REPULSIVE POWERS.

EXPERIMTNT CXXV.—Screw the bottle 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 fig. 22, plate II. by the knob of a poſitively charged bottle, 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

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 bottles, 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 bottle is charged, will fly from one knob to the other, and by thus conveying the fire from the inſide to the outſide of the bottle, 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 bottles which are charged with the ſame power.

Experiment cxxx.—At fig. 58 a wire is fixed

fixed to the under part of the insulated coated phial, 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 bottle, and all the time the bottle is charging, the fly will turn round; when the bottle is charged the needle stops. Touch the top of the bottle with a finger, or any other conducting substance, and the fly will turn again till the bottle is discharged. The fly will electrify a pair of balls positively while the bottle 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 it's 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

thus be driven about on the furface of the glafs, like a feather in the air by an excited tube. The ball being deprived of it's electricity by the pin, it inftantly flies to that part of the glafs which attracts it moft forcibly.

To excite the pane of glafs; 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 PHIAL, AND THE DIRECTION OF THE ELECTRIC FLUID IN THE CHARGE AND DISCHARGE THEREOF, INVESTIGATED BY THE APPEARANCE OF THE ELECTRIC LIGHT.

We have already obferved, that the different appearances of light on electrified points was deemed a criterion of the direction of the electric fluid; that the luminous ftar fhews a point in receiving the electric matter, whilft the luminous brufh, or cone, indicates that it is proceeding from a point.

We fhall now examine the ftate of the different fides of the Leyden bottle by thefe appearances.

EXPERIMENT CXXXII.—Screw the jar I on the infulating 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

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 bottle 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 bottle 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

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 only will 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

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 phial, 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 bottle, 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 bottle be dry, it will in both caſes be diſcharged ſpontaneouſly. See fig. 54 and 55.

Experiment cxxxviii.—An inſulated poſi-

tively charged bottle will give a ſpark from it's 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 phial, 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 bottle 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 is the ſame bottle 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 phial 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 bottle, poſitively charged, be preſented, the appearances in the tube will be as delineated in fig. 62. But if a bottle negatively

tively charged be thus applied, the appearance will be as in fig. 61.

This tube, when mounted on it's 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 Phial.

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 phial, 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 phial 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 phial, and learn that it is the natural boundary to every charge of electricity we can give; and, consequently, that a phial would contain double the charge, in air doubly condensed, as it does in the common atmosphere, since

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 phial 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 bottle 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 a half from the former row complete the circuit, by bringing a diſcharging rod from the laſt wire to the top of a bottle, 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 bottle. 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 bottle; on making the diſcharge, the ball A next the rod was repelled to B, which was again repelled to C, C remained immovable, but D flew to the coating of the bottle.

EXPERIMENT 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 bottle, 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,

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 in an opposite direction from the parts communicating with the negative and positive surfaces.

EXPERIMENT CL.—Let a coated phial be set on an insulating stand, and let it's knob be touched by the knob of another phial negatively electrified; a small spark will be seen between them, and both sides of the insulated phial will be instantly negatively electrified.†

* Atwood's Analysis of a Course of Lectures, p. 121.

† *Encyclopædia Britannica*, Vol. IV. p. 2698.

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 bottle, 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 phial, with the pith balls affixed to it's outſide coating, be ſlightly charged negatively, and then inſulated, bring the knob of a phial, 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 bottle near that of the poſitive one, and a thread will play between them; but when the knobs 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 bottle on which the negative electricity was ſuperinduced, it will inſtantly be diſſipated, a ſmall

a ſmall ſpark will ſtrike the finger, and the bottle 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 ſurpriſing, 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.*

The following among other experiments has been adduced as a ſtrong argument in favour of the impermeability of glaſs. Let a coated phial be ſet upon an inſulated ſtand, and the knob of another coated phial be brought near it; for

* Encyclopædia Britannica, p. 2687.

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 was 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, 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

* Ibid. p. 2687.

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 the glaſs, ſays he, was kept equal on both ſides by the common repulſion. If the quantity on one ſide is diminiſhed, the fluid on the other ſide being leſs repelled retires *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. P. argues againſt.*

* Ibid. p. 268.

Dr. Grey on the Franklinian Explanation of the Leyden Phial.

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 the 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 introduced into one ſurface, but inaſmuch as an equal doſe of natural fire can quit the other ſurface.

Theſe

Thefe affertions are, I apprehend, directly contrary to what really happens; inftead of which, I believe, we may fafely affert, that glafs, and every other known fubftance, may have it's natural quantity of electric fluid either increafed or diminifhed 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 it's furface.

This law, which is perhaps without exception, may be confidered as one of the fundamental laws of electricity, and one upon which many of it's principal phænomena depend. At prefent, I fhall only confider it fo far, at it is the caufe of what is commonly called the charge of a coated jar: fuppofe fuch a jar infulated, and connected by it's 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 furface of the jar. After which, if the finger, or any other conducting fubftance, be prefented 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 electric fluid from the outfide of the jar, cannot

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 before-mentioned 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

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 by 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,

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 ballance 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.

* Dr. Grey's paper, Philoſ. Tranſ. part 1ſt, 1788.

CHAP.

CHAP. XI.

OF THE ELECTRICAL BATTERY, AND THE LATERAL EXPLOSION OF CHARGED JARS.

TO increase the force of the electric explosion, several Leyden phials 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 b, c, d, e, f, g, 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 incon-

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

* 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 and remaining tin-foil.

prepared as to augment it's power. If the ſpark is made to paſs through a hole in a plate of glaſs, 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 bottles.

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 it's 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.

EXPE-

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 it's 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 phænomena are, first, the aperture

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 phænomenon, 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 phænomena, conſidered ſimply, may admit of an eaſy ſolution from the hypotheſis of a ſingle power; when they are taken

 both

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, ex. gr. one 50th 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 a 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

* Atwood's Analyſis.

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 it's 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 3 by 2 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, bring the points of the wires E T, E F, fig. 3, 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 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 it's denſity, which is increaſed when the ſame quantity of fire is compelled to paſs through fewer conducting particles.

The exploſion in melting the ſtripes 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 diſcharger.

EXPERIMENT CLXII.—*To break thick pieces of glaſs.* Place a thick piece of glaſs on the ivory plate of the univerſal diſcharger, fig. 3, pl. II. and a thick piece of ivory on the glaſs, on which a weight

a weight from one to ſeven pounds is to be placed; bring the points of the wires EF ET againſt the edge of the glaſs, and paſs the diſcharge through the wires, by connecting one of the wires, as EF, with the hook C of the battery, fig. 65, pl. IV. and forming a communication, when the battery is charged, from the other wire ET 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 woods 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 GH 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.* Fig. 96, 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 e, 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 ſurpriſing, 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

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 differerent 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

* Atwood's Analysis, p. 119, 120.

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.

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 a half in diameter, and half an inch thick; the ſecond, by four feet and a half of ſmall chain. On diſcharging a jar, containing five hundred

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 before-mentioned, 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,

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 a great number of ſolid ſticks 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.*

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

* Nicholſon's Introduction to Philoſophy, p. 413.

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

The electric fluid endeavours to pafs near the furface of the water where it meets with more refiftance, than if it is forced to pafs through it. This partly arifes from the power the electric fluid has of raifing an expanfive vapour from the furface of the water, which drives off the refifting air.

A difcharge paffed over the furface of a piece of ice will leave on it fmall unequal cavities, exhibiting the fame appearance as if a hot chain had been placed on it.

A difcharge fent through a green leaf tears the furface in various directions, leaving an image in miniature of fome of the effects of lightning. A difcharge will pafs to a certain diftance over fpirit of wine, without inflaming it; but, if the diftance is increafed, it will fet it on fire. From hence it appears, that the facility with which the electric fire is tranfmitted over the furface of moift fubftances, depends on the eafe with which they are turned into vapours.

The difcharge, in melting the particles of metals, drives into it's paffage the conducting vapours which arife from them; and in proportion as the parts of any body are more readily driven into vapour or duft, the fpark will run to a greater diftance.

EXPERI-

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 ſtroke from the repercuſſion 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 his 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 phial, 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 phial diſcharged.

Notwithſtanding this ſurpriſing velocity, it is certain, that both ſides of a charged phial may be touched ſo quickly, even by the beſt conductors, that all the electric matter has not time to make the circuit, and the phial will remain but half diſcharged; and there are ſeveral inſtances where the motion appears ſlow, and not eaſily reconcilable

reconcilable with this immeasurable velocity; and it is also certain, that this fluid is resisted in it's 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 phial, which differs altogether from the received theory.

CHAP.

CHAP. XII.

On the Diffusion and Subdivisions of Fluids by Electricity.

WE are chiefly indebted to the Abbé 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 Abbé'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 spirits 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

their apertures. It does not make any liquor evaporate through the pores either of metal or glaſs.

To extend theſe principles further, the Abbé 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 it's 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 it's 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 Mr. 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 end 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.

EXPERI-

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 bottle 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 it's bottles; 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 ſpark 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

* Nicholſon's Introduction to Philoſophy,

ſhoot out an almoſt inviſible thread into the air, to the length of a yard and 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 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 it's 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

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 it's 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 it's 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 it's passage, and see that the divergence of it's 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

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 rarified.* 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 it's 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,

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 bottle 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

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 phial 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 phial, 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

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 bottle 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

filling barometers; then place a ſmall drop of æther 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 æther 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 it's whole cavity; that the vacuum became a better conductor of electricity in proportion as it was more

 perfect,

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 rarified 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 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 Experiment 112, 113, 121, 122, of this Essay, for further observations on the appearance of the electric light *in vacuo.*

* Phil. Trans. vol. lxxiii. part ii. p. 451.

Experi-

Experiments on Electric Light, by Mr. WILLIAM MORGAN.

1. There is no fluid or ſolid body, in it's paſſage through which the electric fluid may not be made luminous; in water, ſpirit, oil, animal fluids of all kinds, the diſcharge of a Leyden phial, 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 fluid 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

ſmall Leyden phial, 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 electrical 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 it's paſſage through the tube.

If

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 phial, 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 phænomena attend the rarefaction of ether, of ſpirits of wine, and of water.

EXPERIMENT CXCV.—*Spark in rarefied water, ſpirits 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 ſpirits of wine are placed on the ſurface of the mercury, phænomena, 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 it's paſſage through it, is not quite ſo luminous as it is in the vapour of water.

Good ether, ſubſtituted in the room of the ſpirits 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

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 phials 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, it's quantity be increased in any particular part, the charge, in passing through that part, will not appear luminous. Water, spirits 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 it's 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

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 appear 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, it's 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 a 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

metallic conductors with the ground. A powerful ſpark, after falling on the large ball at one extremity of the wire, will be divided in it's 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 it's 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 it's 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 it's 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 it's 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 it's 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 phænomena, 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

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 it's 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

conveyed through any portion of inflammable air, or by condenſing that air, the ſpark may be entirely deprived of it's 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, ſpirits of wine, or any bad conductor, when confined in a tube whoſe diameter is not more than an inch. The reaſon of theſe appearances ſeems 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 ſpirits of wine are in a ſimilar manner brought within the circuit of a battery, a ſimilar effect may be diſcovered; it's particles diverge in ſeveral directions, diſplaying a moſt beautiful golden appearance. The metallic calces are, of all bodies, thoſe

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 it's truth or fallacy.

A mercurial gage B, fig. 1, about 15 inches long, carefully and accurately boiled, till every particle of air was expelled from the inſide, was coated with tin-foil, 5 inches down from it's 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

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 it's way into the

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 it's 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 phænomena 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 it's 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

fallen very low in them; yet upon letting in 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 it's 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 it's limit, when the particles again become ſo near, as to reſiſt the paſſage of the fluid entirely, without employing violence, which is the caſe in common and condenſed air, but more particularly in the latter.

It is ſurpriſing 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 it's inſide, and as ſtrong a charge may ſometimes be procured,

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 phænomena 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,

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, a 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 it's way. If a tube, 40 inches long, be fixed into a globe, 8 or 9 inches in diameter, and the whole be exhauſted, the electric fluid, after paſſing in the form of a brilliant ſpark throughout 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

* 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.

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 $\frac{3}{4}$ 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 it's boiling over, and the bent figure of the tube is adapted for it's inverſion into the ciſtern; for by breaking off the tube at M, within $\frac{1}{8}$ or $\frac{1}{4}$ 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 is 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.

CHAP. XIV.

On the Influence of Pointed Conductors for Buildings.

THE importance of electricity, as well as it's 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 surprising phænomena 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 tract, 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

which is pointed, than to one which is flat or globular; because, in this case, the elasticity of the electric fluid, and it's 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 it's 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 it's electric situation.

Besides, the electric powers must be separated before any body can be electrified; and the point

* See Volta's Paper, Phil. Tran. vol. 72.

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.

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 it's 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 it's 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 connection, 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

the communication cut off, the electric fluid, in passing to the outside of the bottle, 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 it's 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 connection of metal to conduct the electric fluid down to the earth, the building will receive no damage; but where the connection 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. H. 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 bottle, 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 bottle, 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 bottle.

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°, 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

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,

ter, the jar was discharged by a loud and full explosion, and the chain was very luminous.

Mr. H. 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 ballanced by a weight at the other end of the arm; (see fig. 71;) he gave a strong spark from the knob of a charged phial 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 it's 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 by 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

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 ballance, 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

ductor 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 phial was then connected with the prime conductor; it now required 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 ſtained by the overflowing of the fire.

Experiment ccviir.—*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,

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

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

a ſecurity

a ſecurity 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, it's 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 terminated 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 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

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 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 ſurfaces 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 it's ſurface, there will follow an exploſion in the earth as well as the atmoſphere, which will produce concuſſions and

other

other phænomena 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 his 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 of 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 at 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. of the Phil. Trans. p. 138; 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,

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

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 it's 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

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 it's 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 it's 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 it's 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

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 con-

ductors 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 it's 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 it's deſtination. When a quantity of electricity is collected

lected 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.

duced. 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 it's 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

pose 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 it's 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 it's 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

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 it's 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 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

"The conductor, with all it's power of *drawing off* the electric matter, was neither able to prevent the flash, nor to turn it forty-six feet out of it's way. The matter of fact is, 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 of 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 it's 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

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 in 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

"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 surfaces 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 the place of it's destination, but to that it could not easily have got, because of the great quantity of atmosphere which lay in it's 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

tion 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 considerably 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

* 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.

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 it's 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 it's 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 it's 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

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 above-mentioned; 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.

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 phænomena 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 it's preſſure, but alſo by it's 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 ſilk 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 con-

venient. 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 phial.

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 it's 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

nence 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 phænomena 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 it's ſurface very eaſily. But inſtead of this, ſo great is it's 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 it's 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 it's contents on one of the hemiſpheres in a ſtrong flaſh, attended with a ſmart exploſion; vivid coruſcations 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 with her own attire.

Connect a coated phial with the poſitive conductor, ſo that it may be diſcharged with the boards,

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 phials, 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 phials, 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.

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 it's 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 it's coated side with a piece of clean dry flannel, or hare-skin; when this plate

* 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 is well excited, it is to be laid on the table with the electric uppermoſt. Secondly, place the metal 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 it's 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.

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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 it's 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 phænomena of attraction and repulsion, while they are in contact with conducting substances, which is the reason why the

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 it's 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 it's 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 it's 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

of ſome electric, and afterwards ſift upon the electrophorus ſome finely powdered reſin, which will form on it's 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 phial; repeat this operation ſeveral times, and then place the bottle on the cake, and move it over it's ſurface, holding the bottle 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

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 rarified, and it's 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 phænomena 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.

EXPERI-

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 M. 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 M. Lichtenburg's beautiful configuration; firſt made on a reſinous electrophorus, by drawing over it the knob of a charged phial, and then rendered viſible by ſifting powdered roſin 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 fig. 101 and 102, pl. V.

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

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 roſin 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 therefored 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 phial was charged very weakly by one revolution of the electrical machine, and after it's 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 phial was charged by three revolutions of the machine, ramifications appeard upon the plate at a conſiderable diſtance from each other.

EXPERIMENT CCXXIII.—Five or ſix revolu-

tions

tions caufed the electrical fluid to fpread upon the plate in ramifications very near each other. Clofe to each branch a fmall fpace was left uncovered with powder, forming a kind of fhade to the figure. Beyond this fhade the powder lay fmooth, foftening off externally.

EXPERIMENT CCXXIV.—With a very ftrong charge the ramifications were clofe and broad, refembling white feathers with a very broad fhade.

EXPERIMENT CCXXV.—A circular brafs plate with an infulating handle was placed upon the refinous plate, and a fpark from the charged bottle was communicated to the brafs plate which was then taken off by it's infulating handle, and chalk projected, which produced a very regular circle of ramifications about four inches long; proceeding from the circumference of the fpace covered by the brafs plate, and within the circle were a number of irregular figures fomewhat like ftars. A fhock made to pafs through the fame plate generally produced more diftinct ramifications, and fometimes without any ftars within the circle; and if the brafs plate was drawn along towards the edge of the electrophorus whilft touched with the knob of the phial, a very beautiful figure, fee fig. 101, plate V. was produced.

EXPERIMENT CCXXVI.—A phial 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 it's 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 phial 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 it's flame placed about an inch diſtant from the middle of the reſinous plate; then the knob of a poſitively charged phial was

ſuddenly

ſuddenly brought to the flame, and both the flame and phial 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 pow-

ders are contrary: for example, if minium, whoſe electricity is ſtrongly poſitive, and ſulphur, very ſtrongly negative, be powdered together, and then this mixed powder 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.

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 which 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 it's ſurface. In preparing ſuch a plane, by drying,

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 preferable 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 ſattin, 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 it's 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

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 it's 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 phænomena may be increaſed by this apparatus, as it depends

pends 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 5 or 6 degrees, then the receiving plate of the electrophorus, according to this method, will raiſe it's 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; it's principal uſe being to collect and render ſenſible that ſmall quantity of electricity, which would otherwiſe

otherwiſe remain imperceptible and unobſerved.

Hitherto we have adapted our condenſer to the detecting weak atmoſpherical electricity, as brought down by the conductor; but this, though the principal, is 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 phial charged, and then diſcharged by touching it's coated ſides with the diſcharging rod or the hand, appears to be quite deprived of it's 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 phial 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 phial 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

the inflammable air-piſtol, or lamp; eſpecially when a perſon is provided with one of thoſe phials contrived by Mr. Cavallo, which, when charged, may be carried in the pocket a long time. Theſe phials, as they retain a ſenſible charge for ſeveral days, will retain an inſenſible one for weeks and months; or, ſuch a one as cannōt eaſily be diſcovered without the condenſer, in which caſe it becomes more than ſenſible, and ſufficient for the experiments of the inflammable air-piſtol, &c.

Secondly. If you have an electrical machine ſo far out of order that it's 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 it's 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

ratus 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 ſtroaked 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

means than if it were ſtroaked 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 ſtroaking 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 phænomena 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.

EXPERI-

EXPERIMENT CCXXXII.—Take two metal rods of equal diameter, 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, it's 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, it's intensity would be increased to 60.

Conductors of different bulk have not only different capacities for holding electricity, but also the capacity of the same conductor is increased and diminished in proportion as it's 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 not comprehend the whole theory, since even the exten-

sion

ſion 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 it's 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 it's 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

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 it's former ſtation, namely, to 60°; excepting the loſs that the air, &c. may have occaſioned during the experiment.

The reaſon of this phænomenon 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

it's 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.

EXPERI-

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 it's 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 phænomena 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

it's 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 it's 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 ballance 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 it's electricity were very powerful, or it's edges not well rounded,) and will rather

retain it's electricity; ſo that being removed from the inferior plane, it's electrometer will nearly recover it's 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 it's 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 ballanced 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, it's 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 it's electricity, while ſtanding upon the proper plane; ſo that it generally leaves it ſo far electrified, that when

ſeparated

ſeparated from the plane, it will give a ſpark. Indeed this phænomenon 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 it's 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 it's capacity ſo far diminiſhed as to render the intenſity of it's 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 it's 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 appli-

cations from it: nevertheleſs, it will be uſeful to exemplify it by an experiment.

EXPERIMENT CCXXXVII.—Suppoſe a Leyden phial, or a conductor, ſo weakly electrified that it's intenſity is one half a degree, or even leſs; if the metal plate of the condenſer, when ſtanding upon it's proper plane, was to be touched with that phial or conductor, it is evident, that either of them would impart to it a quantity of it's 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 phial, 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 aquires 100 times more electricity from the phial or conductor. It naturally follows, that when the metal plate is removed from the proper plane, it's capacity being leſſened ſo as to remain equal to the 100th part of what it was before, the intenſity of it's electricity muſt become 50°, ſince the intenſity of the electricity in the phial 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

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 phial 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 poorly, 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 it's 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 commu-

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 it's quality.

Now, if by the help of both condenſers, the intenſity of the electricity has been augumented 1000 times, which is by no means an exaggeration, 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 communi-

cated

cated 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.

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 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

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, 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 it's brass case A B O, fig. 76. 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 it's 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 the rain, &c.

I M and K N are two narrow slips of tin-foil, stuck to the inside of the glass C D M N, and communicating with the brass bottom A B. They

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 CDMN, 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 to unſcrew it from it's caſe, and hold it by the bottom AB 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 EF.

Of

Of Mr. De Saussure's *Bottle Electrometer.*

The electrometer used by Mr. De Saussure is nearly the same as that of Mr. Cavallo's. The following

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 it's tension, till the perfect conductor was separated from the imperfect one; whereas, if the conductor had been more perfect, it would have been deprived of it's 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.

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 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 1-20th 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 fig. 11, 12, 13. pl. I.

In

* 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, 15 inches, or two feet long, which unscrews in three or four pieces, to render the instrument more portable; see fig. 11, pl. I. When it rains or snows, the small parapluie, fig. 13, pl. I. is to be screwed on the top of the instrument, as by this it's 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 it's 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 it's mass or thickness is less. It is therefore interesting to discover at

 what

* A conductor raised for the purpose of making atmospherical experiments is meant here.

what height 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 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

were as ſimilar as poſſible, and electrified one of them, ſo that the balls ſeparated preciſely 6 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 4 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 it's 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 4 to 28 lines, nearly in the ſame proportion as before; in the third operation they fell to 19; 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 aperçu*) 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

Distance

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.
15	—	—	29
16	—	—	32
17	—	—	36
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 6 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.

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.

Deſcription

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. 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 thread. 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 phial uninſulated, but ſo concealed, that only the knob is viſible, and we are therefore ignorant of it's 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 bottle, and the balls of the electrometer ſeparate 6 lines; from this ſolitary fact, we ſhall gain no informa-

Description of the Rev. Mr. BENNET'*s Gold Leaf Electrometer,** fig. 10, pl. I.

The foot may be made of metal or wood, and about three inches high, that there may be convenient room to handle the instrument, without touching the glass.

The cylindrical glass, in which the gold leaf is suspended, may be about five inches high, and two inches diameter.

The cap is made of metal, and flat on the top, that the various substances whose electricity is 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 it's rim is about an inch deep, hanging parallel to the glass to keep it clean and dry: within this is another

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 bottle, 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 it's contents and that of the globe of metal, and by this means the intensity of it's charge.

* See his very valuable work, entitled, "New Experiments on Electricity."

circular rim, about half as broad as the other, made to go over or within the glafs, and is therefore lined or covered with leather, or other ſoft ſubſtance, to make it ſit 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 the peg is placed. To the peg, which is made round at one end and 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, 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 glafs is covered and lined with ſealing-wax, as low at leaſt as the outer rim, to render it's 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 po-

ſitively

ſitively by the ſtream of chalk, when the nozzle of the bellows was only 6 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, and making it paſs through a longer tract 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,) fig. 19, pl. I. 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. Pow-

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, fig. 20, pl. I. 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 it's 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

that the leaves will be repelled by a ſtick of excited wax at 10 or 12 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 12 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

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, 15 inches in diameter, and 7 feet long; whoſe ſurface was therefore prodigiouſly larger than that of the pin, yet it's 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

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.

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 it's 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 become ſufficient to affect an electrometer and give ſmall ſparks.

NICHOL-

NICHOLSON's *Doubler.*

Plate I. fig. 9, repreſents the apparatus, ſupported on a glaſs pillar 6½ inches 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. 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

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 connection 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

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 ſortieth 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 ninety-nine 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

quire an electricity of the ſame kind with that of the revolving plate. But the rotation again deſtroys the contact, and reſtores B to it's 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 proportional 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 prin-

 ciples,

ciples, 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 it's uſe, the very ſpeedy manner of it's operation, and the unequivocal nature of it's reſults.

Of Mr. Brooke's *Electrometer for charged Jars and Batteries.*

This article might have been introduced with greater

Brooke's Miſcellaneous Experiments and Obſervations on Electricity.

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.

Fig. 96, pl. V. exhibits the electrometer in miniature, as it appears when it is ready to be uſed.

Fig. 96, B, pl. V. is an arm, the ball of which is to be laid to make a communication with a battery.

Fig. 97, pl. V. is the lower part of the electrometer, ſeparate from the upper part.

The arms F H, f k, fig. 97, pl. V. are, when in uſe, to be placed as much as poſſible out of the atmoſphere of a jar, battery, &c.

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 repul-

ſive 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 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, &c.

Mr.

* Phil. Tranſ. vol. 82, p. 384.

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 rarified air, as in an exhauſted receiver. Therefore at a great height, where the air is equally, if not more rarified than in our receivers, it's 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 ſubtil 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

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 reflux, currents, &c. which will alter it's local density. Thus also this fluid, which is contained in our globe, cannot be long uniformly spread through it's mass, as there are ten thousand agents, which will either accumulate or rarify 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 phænomena 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; it's 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

* 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.

and their relation to the other phænomena of the weather. His apparatus was admirably well adapted for this purpose, and superior to any thing that we are at present acquainted with, for intimating easily and at all times the electricity of the air. It not being at 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, one hundred and thirty-two 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

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 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. Mr. de Saussure has already made the experiment with a balloon made of taffety, containing two hundred 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

Faujas de St. Fond, Description des Experiences Aerostatiques, tom. II. p. 271.

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, confirms 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

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 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

ſerved 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, cauſed by the clearing up of the weather, continues in it's 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

* 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.

tricity 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 the 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,

trary, 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

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

to it's 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 it's 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 the 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 it's 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

com-

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 it's 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 winds 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 above take place, an electricity entirely ſimilar to the former ariſes as ſoon as the ſun has ſet; only it's 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 it's 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

cording 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 ſchoolboy'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 heavy

heavy chair in the room. 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 18 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 phial, 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 phial, by which the quality will be ſhewn even at ſome days diſtance.

If a charged phial is carefully kept from any of thoſe means by which it is known to be diſcharged, it will retain it's charge for a long time. On this principle the above-mentioned phial is conſtructed; the bottle 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 phial, having a piece of tin-foil connected with it's 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 bottle 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 phial; and, as the fire cannot now escape easily, the charge of a phial 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

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

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 phial to it, rises surprisingly quick to it's 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 in 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

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 phænomena, it is rather surprising that philosophers have

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 it's 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 phænomena, 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 phænomena. 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

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 connection 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 it's 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 10 days which gave no ſigns of electricity; 17 days, including the foregoing 10, in which he could obſerve no electricity in the morning, though it became very ſenſible at noon, and was very much increaſed towards the ſetting of the ſun.

Every

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

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 not 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

great

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 necessity 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. Transf. 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 minues 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

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.

Mr. 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 cannot. 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 it's relation. Thus, in ſtormy weather, we ſee the electricity ſtrong, then null, and in a moment after ariſe to it's former force; one inſtant poſitive, the next negative, without being

 able

able to aſſign any reaſon for theſe changes. Mr. 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 inteſſity 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 it's 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; Mr. 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,

winter, (during which moſt of Mr. 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; it's 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 reflux, which cauſes it to increaſe and diminiſh twice in 24 hours. The moments of it's 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.

Mr. 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 it's ſituation, indicated an electricity equal to what it would have ſhewn if it had been placed on an open plain. The height of the barometer is reduced to what it would have been if the mercury had been conſtantly at the temperature of 10 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 phænomena. 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.

TABLE

T A B L E.

d.	h.	m.		Barometer, feet in height.	Thermometer.	Hygrom.	Electrom.	
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. & approa.
	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 18 observations of this table, when the sky was quite serene, we see that the electricity was pretty strong at 9 in the morning, that from thence it gradually diminished till towards 6 in the evening, which was it's first minimum; after which it increased again till 8, it's second maximum, from whence it again gradually declined till 6 the next morning, which was the time of it's 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 3 or 4 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 diur-

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nal 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 phænomena, Mr. De Sauſſure inſtituted a ſet of experiments on evaporation, avoiding the uſe of Mr. De 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 ſilk 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 ſome of the circumſtances, but the reſult was always the ſame.

As it was not eaſy to think ſo able a philoſo-

pher 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 silk 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.

Mr. De Saussure suspected, that the intensity of heat to which the water is exposed, by the contact of a body in a state of incandescence, was the cause of the electricity produced by it's evaporation, and that a combination was then formed, by which a new quantity of the electric fluid was produced. This conjecture may at first

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, 5 inches high, 4 in diameter, and 6 lines thick, was heated red hot, then inſulated; after which, ſmall quantities of water were thrown into it, each

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 connection with another mentioned by Musschembrock, 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, Mr. 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

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, 15 lines thick, and 4 inches diameter; this was inſulated by a dry glaſs goblet; upon this pot was placed the crucible, or any other heated ſubſtance, on 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 Muſſchembrock 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 19 ſeconds to evaporate the water,

water, and took more time till the third projection, when it took 35 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 o, then positive, afterwards negative, then o, and afterwards positive to the end of the experiment. The vapour was not visible till the 7th 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 it's 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.

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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 5 minutes, 6 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 spirits of wine in a silver crucible; here there was no electricity produced at the two first projections, and what was afterwards obtained was negative.

Twelfth experiment with ether; here the electricity was also negative. These two inflammable

flammable 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 Mr. 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 ſubtil. 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 plea-

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ſure 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.

bability. But the phænomena 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.

Mr. 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 it's 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 were 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 it's 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 it's energy. When the vapours have changed their form, it deſcends active, animated with a penetrating and expanſive force; the 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

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 ſunſet, 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 uninterrupted 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 it's 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

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.—Mr. 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 phænomena, 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, ſeem 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.*

red. The apparatus for this purpoſe is ſeen in fig. 94. AB 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 it's 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.

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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 it's 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.

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 it's abſorption by the cement, with which the glaſs tubes employed in the laſt experiment

experiment were clofed, he repeated it with the air from quickfilver, in a glafs fyphon confined by quickfilver, and the refult was the fame.

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 fimple electric fpark from a conductor of a moderate fize, for the fpace of five minutes without interruption, in a quantity of vitriolic acid air, without producing any change in the infide of the glafs; when immediately after, making in it only two explofions of a common jar, each of which might be produced in lefs than a quarter of a minute with the fame machine in the fame ftate, the whole of the infide 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 refult of that combination, all the difference that would have rifen from the fimple fpark or the explofion, could only have been a more gradual, or a more fudden formation of that matter.

A large phial, about an inch and a half wide, being filled with this air, the explofion of a very large jar, containing more than two feet of coated furface, had no effect upon it; from which

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 from ſomething adhering to it, there was leſs of the whitiſh matter; and at laſt, nothing but black matter was produced, as in all the

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 vitrolic acid air, as they ſeem to reſemble one another very much.

The electric ſpark or exploſion, taken in common

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, 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, pl. I,

the

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 it's 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; 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 fig. 17, pl. I, 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,

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 the 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 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 1 ½ to ¾ of an inch.

It is ſcarcely neceſſary to inform any one uſed to electrical experiments, that in order to force

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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 ball 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 it's 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

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 ri-

ſing to the top of the tube M, divided the ſoap-lees into it's 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

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 it's 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 it's 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 it's phlogiſton by evaporation to dryneſs, and expoſure for a few weeks to the air, loſt the property of precipitating ſilver from it's ſolution; a proof that this property depended only on it's phlogiſtication, and not on it's 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 it's 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

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 it's 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 just been 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

pended by a ſilk ſtring, or other inſulating ſubſtance: bring the braſs knob of a charged bottle 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 bottle, and ſtand as in plate I. fig. 21: continue to hold the bottle in the ſame poſition during a few ſeconds, and one of the ſlips will bend towards the knob of the bottle, fig. 21, and ſtrike it ſuddenly, then it will ſtand repelled till it's 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 bottle, 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

obſerver loſes the opportunity of watching the momentary and intereſting change which happens in ſeveral ſtates of the atmoſphere, eſpecially during the paſſage of thunder-clouds.

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 the 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 10 feet long, ſee pl. I. fig. 10, 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

taining 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 ſel-

dom

dom 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.

CHAP. XX.

Of Medical Electricity.

THE Abbé 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;

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 it's 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 by night and day, to maintain an equilibrium that is continually varying.

ing. 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 it's 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 it's exiſtence, and as electricity exhibits ſo many phænomena, 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

The agency of this fluid, and it's exiſtence in animated nature, has 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, is 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 it's 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 it's 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

from Mr. Walſh's experiments, that the will of the animal commands the electric powers of it's organs. If theſe reflections 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 it's 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

* Sir John Fringle's Diſcourſes, p. 84.

think of attemping 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 surprised to find her whole body electrified, and darting out sparks of fire against every object that approached her. Her hair was strongly electrical, 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 strokes 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 subtle 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, it's 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 it's abſence: nor can this appear ſurpriſing, 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

taining 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 it's 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 it's life. This experiment is taken from Mr. Cavallo's treatiſe on medical electricity. It's importance is ſelf-evident, and it certainly merits a further inveſtigation by thoſe who are acquainted with the animal œconomy, 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. It's 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 ſurpriſing, that many diſorders have been refractory to it's 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 it's infancy, when it had to combat againſt fear, prejudice, and intereſt, it's 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,

ſtruent. 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 it's 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 it's 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 it's action in each caſe varied, by cauſing the fluid to paſs through materials which reſiſt it's paſſage in different degrees; it may be applied to the naked integuments, or to the ſkin covered with different reſiſting ſubſtances; and it's power may be rarified or condenſed,

denſed, 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 bottle 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 repreſents the directors; the handles are of glaſs. A is a braſs wire with a ball on it's end. The wire of one is bent, for the more conveniently throwing the electric fluid on the eye, &c.

&c. The balls may be unſcrewed from the wires, and the wooden point B ſcrewed in it's 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 electric forceps: ſome gentlemen think it is a very convenient inſtrument for communicating a ſhock. It's uſe is evident from an inſpection of the figure.

Fig. 85 is the medical bottle, 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

cemented a brafs focket D, furnifhed with a fpring tube E; the wire F moves in this tube, fo that the ball G may be fet at a convenient diftance from the ball H. The end I of the bent piece of glafs is alfo furnifhed with a fpring tube, which flides upon the wire K, communicating with the infide of the bottle.

To ufe this botle, place the ball H in contact with the conductor, or conect them together by a wire, and then charge it in the ufual manner. Now, if a wire proceeds from the ball L to the outfide coating, the bottle will be difcharged whenever the fluid has acquired fufficient force to pafs through the fpace of air between the two balls; confequently the fhock is ftronger in proportion as the diftance between the two balls is increafed.

It is obvious, that when the electrometer is thus connected, it acts in the fame manner as a common difcharging rod, and forms the communication between the outfide and the infide of the bottle; with this difference only, that the diftance of the end which is to communicate with the infide may be limited and regulated.

It has been found more convenient, to feparate the electrometer from the bottle, and apply it to the conductor: fee in the frontifpiece to this Effay, where *a*, *b*, repreefents the electrometer,

ter, *c*, *d*, the Leyden bottle, ſuſpended at a ſmall diſtance from it; a glaſs tube *e*, *f*, 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 bottle, and touches it's internal coating, the other only goes to the coating of the tube: theſe wires may be removed at pleaſure. The bottle 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. 119, pl. V. repreſents the bottle director, which is hollow and coated like a common bottle, acting in all reſpects like one, but is convenient from it's 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 bottle 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 bottle, and the other with the electrometer; the ſhock or ſtream may be conveyed to any part, with the greateſt facility. It is alſo evident,

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.

Firſt, 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

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 twofold manner: 1st, By insulating the patient, and connecting him either with the cushion or the positive prime conductor, the operator presenting the point. 2nd, 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 woollen cloth or flannel. The patient may be seated in an

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 the 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 it's 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*

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 bottle. This is conveniently effected, by connecting one director by a piece of wire with the electrometer, and the other with the outſide of the bottle; 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 bottle with the glaſs tube is uſed as a common bottle, 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

chattering noiſe of the ſpark in paſſing to the electrometer, the reſiſtance formed to the diſcharge is ſo great, that the fluid cannot force it's 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 bottle, and leaving the ſhorter one which is connected with the tube in it's 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 bottle 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*

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, fig. 119, plate V. 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 of inside of a large charged jar, and then this apparatus used in the foregoing manner will discharge from the large jar, at each spark, it's 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 Phial 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 con-

denſed in the phial will be thrown on the part in a denſe ſlow ſtream, attended with a pungent ſenſation, 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 adviſable 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

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 it's 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.

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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 inſtru-

ment, 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 it's 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 it's 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

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 compriſed 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 concentred 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 it's 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

When I wish to apply the fluid, I connect by a smooth wire the glass-mounted director to the conductor with a point at it's 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 twofold 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

dour 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.

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The indentation 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 appearances of relapse being observed on the 10th 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, chusing to depart from the system I recommended on the third day, drew some sparks, and passed a few slight shocks though 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

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:

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

the parts, to which he readily ſubmitted, though he laughed at the propoſal; the inſtant relief he found from it's 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

About two years ſince, this ſame gentleman finding a little girl, about 9 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 impoſſible 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;

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 innoculated it for the ſmall-pox.

An infant of ſix months, remarkably healthy, and born of very healthy parents, was innoculated 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

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

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

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 experiment of electricity, when other means failed of success, and the result of repeated experiments was remarkable.

A young man, aged 22, had been 6 months afflicted with an ague, which at it's 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 it's 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 sto-

mach, 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 3 minutes his rigor ceaſed: in 15 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 paroxyſm ceaſed; the ſucceeding day he found himſelf much better than uſual. I continued to electrify him in the ſame manner the 4 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 ſer-

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

vanifhed, and never returned. By the advice of the phyfician, he continued the bark a few days, and recovered his health.

A maid fervant was afflicted with a fimilar complaint, which refifted the bark; I electrified her with the fparks, and ftopped the pain: fhe remained well 14 days, and then an heavy wafh renewed the pain: I electrified her a fecond time in the fame manner, and completed her cure.

A fervant in the Temple had been long afflicted with a quartan; I electrified him at the accefs of the cold fit, by the frictions applied to the ftomach, and extracted from the fpine, and ftopped the rigor; no fever enfued, and he remained well one month. When waiting for his mafter at the Houfe 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 fucceeded in ftopping the fit the firft time I applied them: I afterwards electrified him every fourth day, for one month, and his ague did not return.

I did not efcape myfelf from an attack of intermittent fever. My friend, Dr. George Fordyce,

Fordyce, directed for me an emetic, and ſome febrifuge draughts; after the ſecond fit, he ordered the cortex, of which I took an ounce and 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 15 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 con-

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tinued 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 8 o'clock in the morning I found the fever beginning it's 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 9 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 lying-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; stimulents 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 vermillion colour every day, for several hours after the application; in less than 3 weeks she was perfectly recovered.

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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 3 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

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, beside 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 3 successive years, he wished to have a course of electric operations, which he thought *reanimated* his nerves. He is at present living, and enjoy-

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ing a ſtate of health, enabling him to uſe daily horſe exerciſe, with a chearful 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 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 14 days, came

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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 workhouſe pregnant, had been obliged to labour, almoſt barefoot, 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 reme-

dies

dies 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 her 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, 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

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.

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 6 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 at-

tend 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 it's 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 it's 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 reabſorbed, 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, it's ſize reſtored, and the leg perfectly uſeful. He was deſirous of returning home, and accordingly was preſented cured from the hoſpital.

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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 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

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 it's size and power, the contraction almost removed, and the swelling very much abated. I continued the shocks 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 it's 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

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 advan-

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tage 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

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 9 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 ſmalleſt.

N O T E.

Take an orange, or an onion, place the directors on it's 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

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 it's 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

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 farina 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,

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

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. Blanc'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

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

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 judgement, 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 *deſiciency* 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

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.

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 agitations 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

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 it's 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's, 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 bottle, 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 ſurpriſed, 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 bottle; this likewiſe produced no other effect than a ſlight head-ach, which laſted for an hour. I choſe to omit two days, and then repeated the experiment; the patient ſtrongly expreſſing himſelf ſatisfied, that this was the moſt likely means to do him ſervice. I was, myſelf, moſt ſurpriſed that I could practiſe 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,

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 horſeback, went a long journey, and has remained well 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 inconveniencies 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 it's 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

covered the retentive power, I had not 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 it's retentive power, and her ſpirits were remarkably low; ſhe would not ſpeak the whole day, ate little,

little, and ſlept ill. Within an hour after I had electrified her, the following day, ſhe ſpoke, grew more chearful, 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 chearful, 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 life was extinguiſhed: how long he had been ſuſpended

was

was not to be aſcertained with any accuracy. He was conveyed to a houſe, where all poſſible aſſiſtance was given him 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 ſurpriſing; 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

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, 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

gical 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 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 it's *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 it's ſalutary effects, the knife will be with-held, till a fair and candid trial of it's 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.

FINIS.

A CA-

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A

CATALOGUE

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	£.	s.	d.
Complete equatorial inſtruments, from 50gs. to	500	0	0
Tranſit inſtruments, aſtronomical quadrants, circular inſtruments, according to their ſizes, the variety and accuracy of their adjuſtments.			

Mathematical Inſtruments, for Geometry, Drawing, &c.

Plain compaſſes for meaſuring lines, from 1s. to	0	5	0
Drawing compaſſes with moveable points, from 5s. 6d. to —— ——	3	3	0
Drawing pens, from 1s. to ——	0	5	0
Bow compaſſes for deſcribing ſmall circles, from 3s. to —— ——	0	5	0
Hair compaſſes for taking extents with accuracy	0	7	6
Beam compaſſes for deſcribing large circles, laying down diviſions, &c.			
Triangular compaſſes for transferring three points at once from any plan or drawing, from 18s. to	1	1	0
Proportionable compaſſes for diminiſhing plans, or drawing in any aſſigned proportions	1	11	6
Elliptical compaſſes with friction rollers, for drawing ellipſes ——	4	4	0
Elliptical compaſſes on a different conſtruction, anſwering at the ſame time the purpoſes of beam and calliper compaſſes ——	4	4	0
Spiral compaſſes for deſcribing ſpirals, anſwering alſo as beam and elliptical compaſſes, from 6l. 6s. to —— ——	11	11	0
Parallel rules of various conſtructions			
A new-invented parallel rule, which for facility in application, and accuracy, exceeds any other kind, from 8s. 6d. to ——	1	1	0
Ditto with a protractor			
An inſtrument for drawing lines inclined in a given angle to each other, though the angular point is at an immenſe diſtance, a rule exceedingly uſeful in perſpective			
Various inſtruments for the purpoſe of dividing lines, or transferring diviſions on paper			
A cyclograph, or an inſtrument by which circles may be deſcribed, from 4 or 6 inches radius to one as large as the orbit of the Georgium Sidus	6	6	0

	£.	s.	d.
Plain ſcales and ſectors of different ſizes			
Square protractors, ſemicircular and circular			
Pocket caſes of drawing inſtruments, from 7s. 6d. to	5	15	6
Magazine, or complete collection of drawing inſtruments, at 11l. 11s. at 17l. 17s. and from thence to —— ——	50	0	0
Perſpective compaſſes for aſcertaining the relative proportion of objects ——	0	18	0
A new invented inſtrument for taking views, &c. which will facilitate the operations of the artiſt, and greatly aſſiſt beginners ——	3	3	0
A ditto for drawing on an horizontal plane	5	5	0
Pantographers for copying, reducing, and enlarging drawings, from 2l. 12s. 6d. to ——	6	6	0

Surveying Inſtruments.

Caſes of drawing inſtruments. — Parallel rules. — Plotting ſcales. — Sets of plotting ſcales. — A new-invented parallel rule, with plotting ſcales. —A parallel rule and protractor			
A plotting ſcale, in form of a beam compaſs			
Protractors for laying down angles			
Ditto with a nonius and moveable limb —	2	12	6
Ditto rendered more accurate, as the limb is made to move with a tooth and pinion ——	4	14	6
Meaſuring wheels —— ——	6	16	6
Pedometers for meaſuring a given diſtance in walking			
Meaſuring chains of 50 and 100 feet			
Gunter's chain —— — —	0	7	6
Tape boxes, according to the length			
Surveying croſs or ſquare —— —	1	11	6
Plain tables, with an index and ſights; by theſe the plan is taken on the ſpot, and does not require a future protraction — —	3	13	6
Beighton's improved plain table, with an index of a peculiar make; in this inſtrument the line of ſight is always over the center of the table, the ſtation lines are alſo drawn parallel to thoſe meaſured on the ground —— ——	14	14	0

Theo-

	£.	s.	d.
Theodolets, or inſtruments for meaſuring angles, diſtances, &c. are made in various ways, ſome being more ſimple and portable, others more accurate, and with a greater number of adjuſtments			
Theodolets, with four plain ſights, and a compaſs box, from 5l. 5s. to ———	5	15	6
A ſmall theodolet, with teleſcopic ſights and vertical arch —— — —	9	9	0
An improved ſmall theodolet with rack motions			
A larger ditto, in which the limb of the theodolet is made to ſerve occaſionally the purpoſe of a protractor —— ———	14	14	0
A ditto of the ſame ſize, on a different conſtruction, the vertical arch being fixed to a long axis; the limb does not ſerve for a protractor	14	14	0
A larger ditto, like the preceding, only moving with rack-work —— — ——	21	0	0
The lateſt improved theodolet, with double teleſcope, and every requiſite adjuſtment			
Circumferenters, the principal inſtrument uſed in America, from 2l. 2s. to ———	4	14	6
An improved circumferenter, ſo contrived, that the operator need not reſt the truth of his work entirely on the needle; it may be alſo uſed to take altitudes			
Air or ſpirit levels with teleſcopic ſights, from 4l. 14s. 6d. to —— ——	12	12	0
Air or ſpirit levels with plain ſights ——	1	11	6
Station ſtaves with ſliding vanes for levelling	1	16	0
A ſmall ſurveying compaſs, with ſights, a nonius diviſion, and three-legged ſtaff —	4	14	6
A ſmall ſurveying compaſs and ſingle ſtick	2	2	0
(The two foregoing inſtruments are portable and light, and may be put with eaſe in the pocket)			
Miners compaſſes, uſed for carrying on works under-ground, from 10s. 6d. to ——	1	1	0
Ditto with a ſmall teleſcope fixed to one ſide	1	11	6
Green's teleſcope and tangent board, for meaſuring diſtances at one ſtation: (it is obvious, that on the meaſuring of a ſtrait line with accuracy, the whole buſineſs of ſurveying depends; Mr. Green's method is certainly more expeditious than any other, and is not liable to objections which may be made to them)			

Optical

	£.	s.	d.
Optical ſquare, a ſmall inſtrument for ſurveying by right angles; it requires no ſtaff, and may be eaſily corrected or adjuſted ——	1	16	0
An optical inſtrument for determining with accuracy when objects are in a ſtrait line —	1	7	0

Apparatus for Experiments on Magnetiſm.

An apparatus for explaining the principal phænomena of magnetiſm, from 3l. 3s. to —	15	15	0
Magnets			
Small compound magnets			
Horſeſhoe magnets			
Compound ditto, from 15s. to ——	21	0	0
Dipping needles from 12l. 12s. to ——	31	10	0
Variation compaſſes, 2l. 12s. 6d. to —	21	0	0

Inſtruments for Experiments on Pneumatics.

A ſmall ſingle-barrel air-pump ——	2	12	6
A ſmall double-barrel ditto ——	4	14	6
A larger ditto —— ——	6	16	6
A table air pump ——	10	10	0
The American double barrelled air pump, the lateſt improvement on this inſtrument, in which the air receives no impediment from the action of valves or cocks, exceeding Smeaton's in accuracy and ſimplicity, and far ſuperior in both reſpects to ſeveral later contrivances			
A condenſing engine; this may be, if deſired, combined with the former, but the rational and practical experimentaliſt will find many advantages in having them detached from one another			

Apparatus for an Air Pump.

The madgeburg hemiſpheres, from 12s. to	1	11	6
A flat plate and collar of leathers for placing on open receivers —— ——	0	15	6

Guinea

	£.	s.	d.
Guinea and feather apparatus, for experiments on the resistance of the air, from 18s. to —	1	11	6
A set of mills for ditto ———	1	11	6
A ditto on a better construction ——	4	4	0
Bell apparatus, for shewing that a vacuum does not communicate sound ———	0	5	6
Ditto on a better construction			
Ditto with wheel-work, by which the bell may be put in motion or stopped at pleasure —	3	18	6
A new apparatus for striking flint and steel in vacuo			
An apparatus for firing gunpowder in vacuo			
A copper bottle, beam and stand, for weighing of air	2	16	0
A box bladder and lead weights, to shew the elastic power of the air —— ——	0	15	6
Ditto on an improved plan ———	0	18	0
A model of a pump, illustrating at the same time the nature of pumps, and proving that there is no such thing as suction ———	1	5	0
A small receiver and plate, which clearly evinces that receivers are kept on the pump by pressure, not suction ——— ———	0	12	0
A filtering cup —— ——	0	5	6
A plate and piece of wood ———	0	4	6
(The two last articles are for shewing the porosity of vegetables)			
The torricellian experiment			
Fountain in vacuo —— ——	0	5	6
Ditto on a different construction ———	0	18	0
Lungs glass —— ——	0	5	6
Ditto on a different construction			
A single transferer plate and pipe for a fountain	0	15	6

Instruments for Navigation.

Cases of instruments, and telescopes of different kinds, sizes, and prices			
Night telescopes, from 1l. 11s. 6d. to —	2	2	0
Opera glass for the same purpose ——	1	11	6
A telescope with an eye-glass micrometer, for determining the distance of a ship at sea			

Hadley's

	£.	s.	d.
Hadley's quadrants in mahogany frames —	2	2	0
Ditto in black ebony frames ———	3	3	0
Hadley's sextant in wood —— ——	6	16	6
Ditto in brass, on the most improved plan, from 11l. 11s. to ——— ———	15	15	0
Knight's steering compass, with improvements	2	12	6
Knight's azimuth ditto — —	5	15	6
Ditto on friction wheels ———	10	10	0
Marine barometers; by these storms have been foretold at sea some hours before they happened			
Circular instruments, to answer the purpose of the sextant			
Dipping needles, from 12l. 12s. to —	31	10	0

Meteorological Instruments.

A plain portable barometer ———	2	2	0
Ditto with a thermometer ———	3	3	0
A plain barometer, covered frame and glass door	2	12	6
Ditto with a thermometer ——	3	13	6
A barometer with a long cylindric thermometer	4	4	0
A ditto with ditto, and De Luc's hygrometer	7	7	0
A barometer and thermometer, with a guage, the indexes moving by rack-work ——	5	15	6
A barometer for measuring the altitude of mountains, &c.			
Marine barometers			
Diagonal, wheel, and statical barometers			
Fahrenheit's thermometers, from 1l. 1s. to	2	12	6
Ditto for botanic purposes ——	0	18	0
Ditto for the brewery —— ——	1	1	0
De Luc's hygrometer; these are the only instruments by which comparative observations can be made on the dryness and moisture of the air, from 3l. 3s. to —— —	7	7	0
Rain guages			
Dr. Lind's wind guage			
Hygrometers with the beard of the wild oat	0	10	6
Fontana's eudiometer for ascertaining the purity of the air —— ———	2	5	0

Instruments

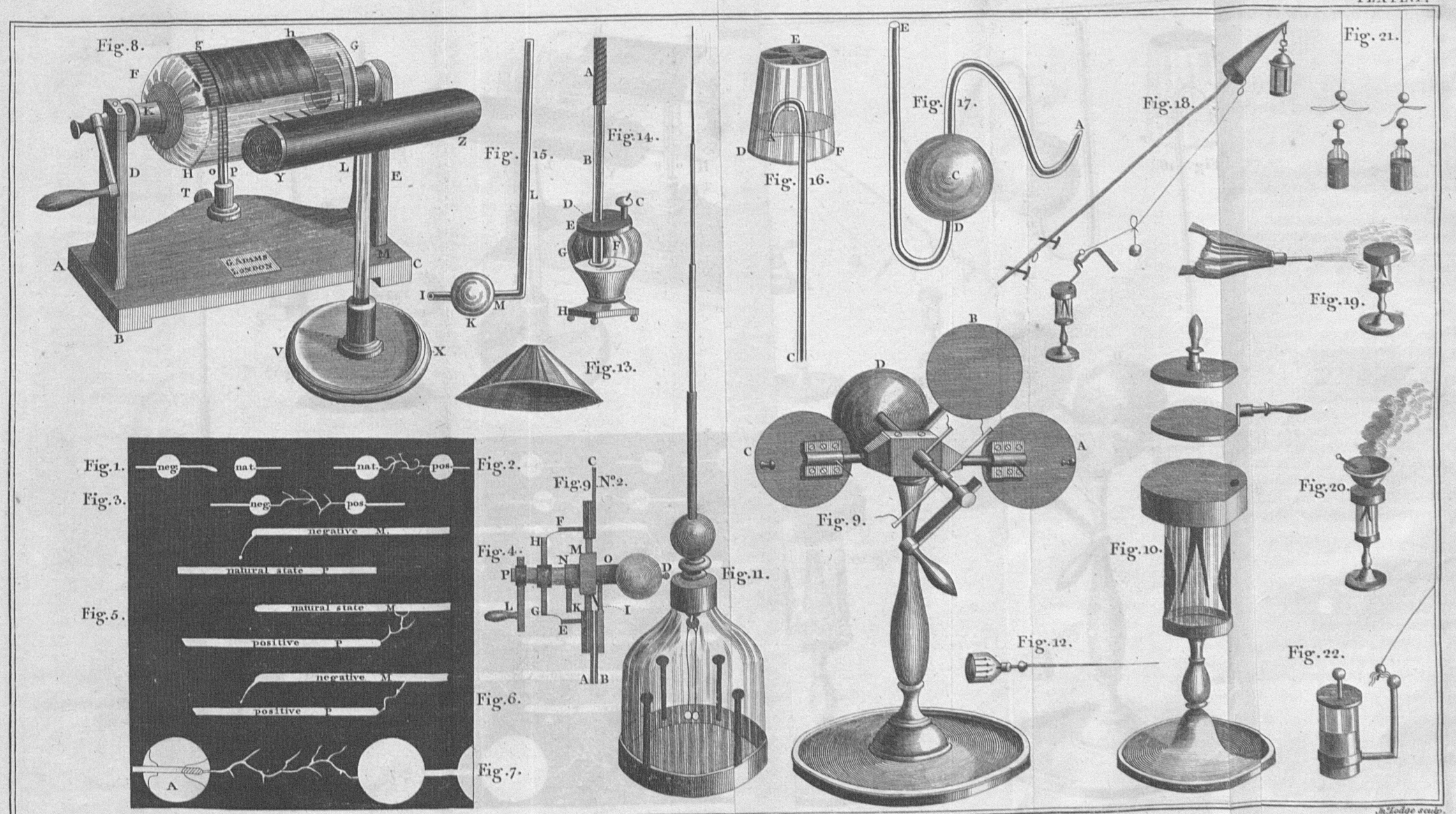
Inſtruments for illuſtrating the Mechanic Powers, the Laws of Motion, &c.

	£.	s.	d.
A conciſe apparatus for illuſtrating the nature of the ballance, the pulley, the different kinds of levers, the inclined plane, the wheel and axle, the ſcrew, a compound engine, and a compound lever; alſo, a double cone to move up an inclined plane, and other pieces to ſhew the properties of the center of gravity, from 21l. to	26	5	0
A ditto on a more enlarged ſcale			
Atwood's apparatus for demonſtrating with accuracy the laws of accelerated and retarded motion. It is one of the moſt pleaſing and ſcientific inſtruments in mechanics, as well from the variety of experiments that may be made with it, as the accuracy with which they are performed	26	5	0
A machine for illuſtrating the theory of central forces; in this machine the times are marked by ſound, the ſpaces are ſhewn by an index, the errors ariſing from friction are ſo far leſſened as to be ſcarcely ſenſible —— —	31	10	0
Pullies of various combinations and conſtructions			
A ſmall carriage, inclined plane, wheels of different ſizes, &c. for experiments on wheel carriages			
Roberval's paradoxical ballance			
Cycloidal lever, ſee Emerſon's Mechanics, prop. 20, 25.			
Compound ſteelyard			
An apparatus for experiments on colliſion			
Ditto for illuſtrating the compoſition and reſolution of motion			
Pyrometers on various conſtructions			
With many other articles and models for experiments on friction, pendulums, &c. too numerous to be comprized in a ſmall catalogue			

Inſtruments

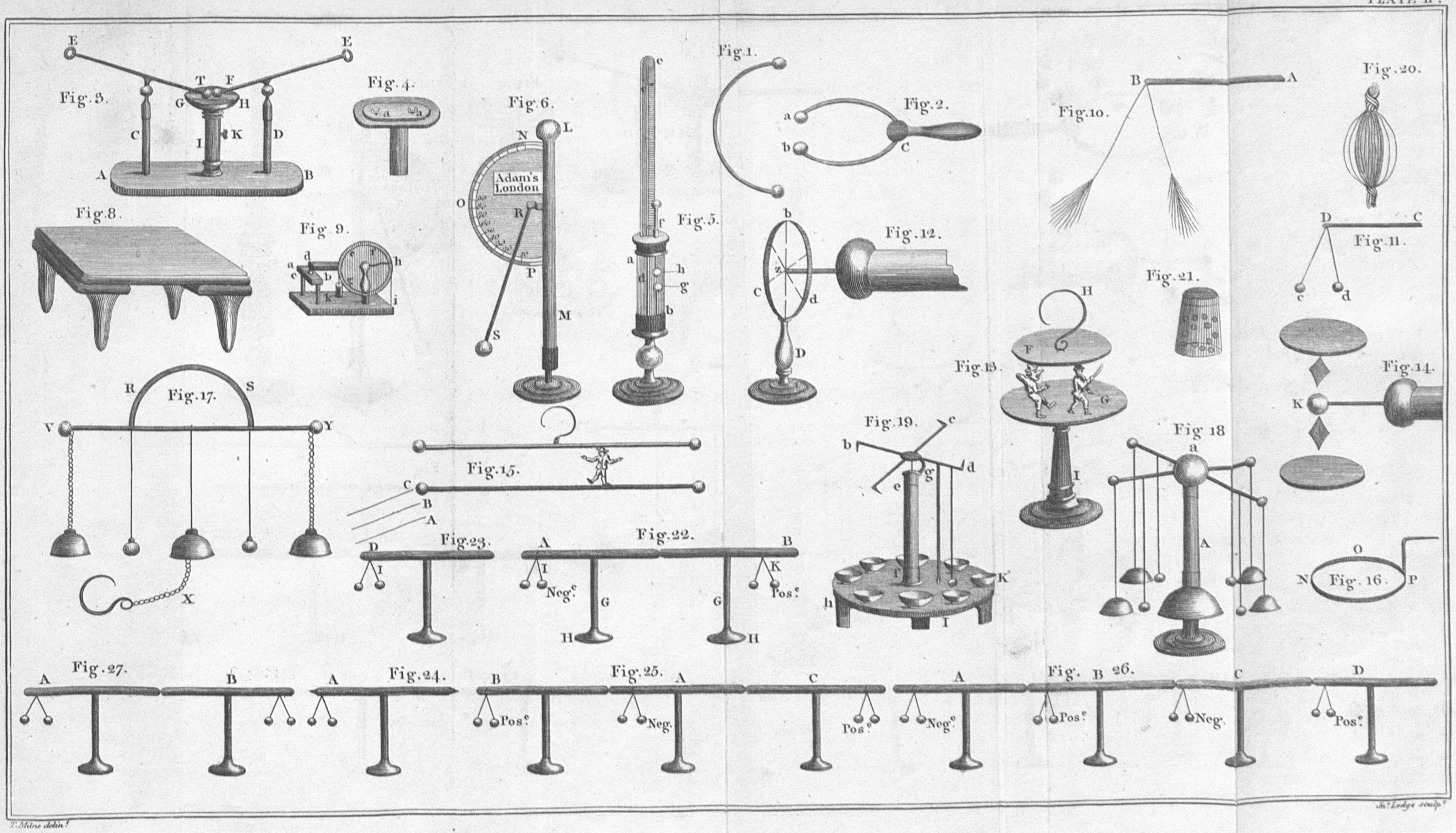
Inſtruments for Experiments in Hydroſtatics and Hydraulics.

	£.	s.	d.
Hydroſtatic ballances, from 2l. 2s. to —	10	10	0
Nicholſon's improved hydrometers, for aſcertaining the ſpecific gravity of bodies			
Ditto for examining of coin			
A conciſe apparatus for experiments on hydroſtatics	21	10	0
An apparatus for ſhewing that fluids have weight			
Ditto for ſhewing that the particles of fluids exerciſe their preſſure independently one of the other			
Ditto to ſhew that fluids preſs in every direction			
Ditto to demonſtrate the lateral preſſure of fluids			
Ditto to ſhew that, *cæteris paribus*, the preſſure of fluids is as their perpendicular height			
The hydroſtatic paradox			
The hydroſtatic bellows			
Apparatus for illuſtrating the laws of preſſure and equilibrium between heterogeneous fluids			
Ditto for illuſtrating the actions of fluids upon bodies immerſed in them			
An apparatus for experiments on ſpouting fluids			
Hydrometers for proving ſpirits, from 1l. 11s. 6d. to	4	14	6
An apparatus for making experiments on capillary tubes			
The model of the diving bell			
A glaſs model of the lifting pump			
A ditto of the lifting and forcing pump			
Hiero's fountain in copper japanned			
Ditto double			
Fountain of command			
A japanned copper fountain to act by condenſed air with a variety of jets			
Apparatus for experiments on ſyphons.			



T. Milne delin.

W. Lodge sculp.



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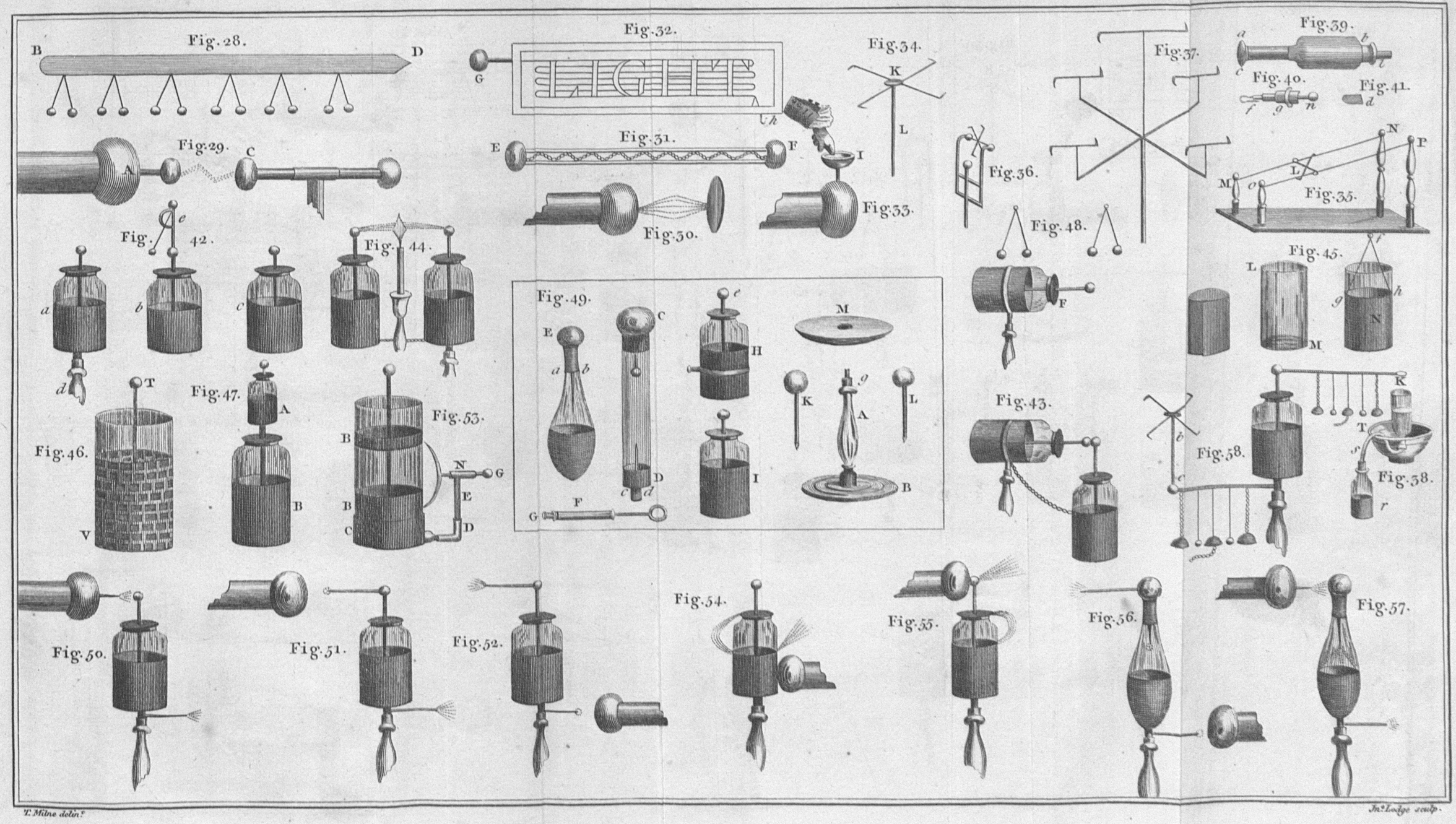
Jn.o Lodge sculp.e



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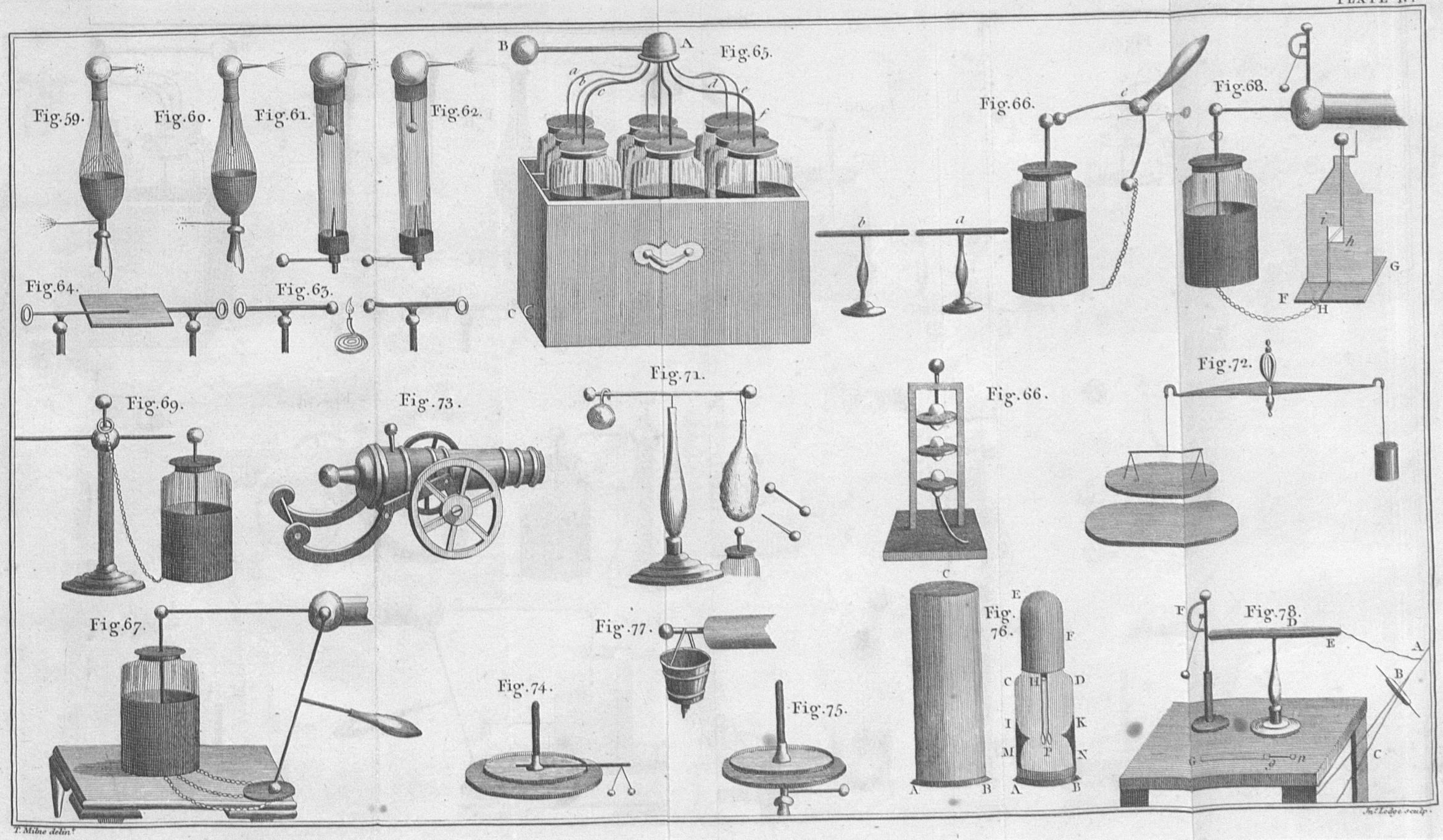

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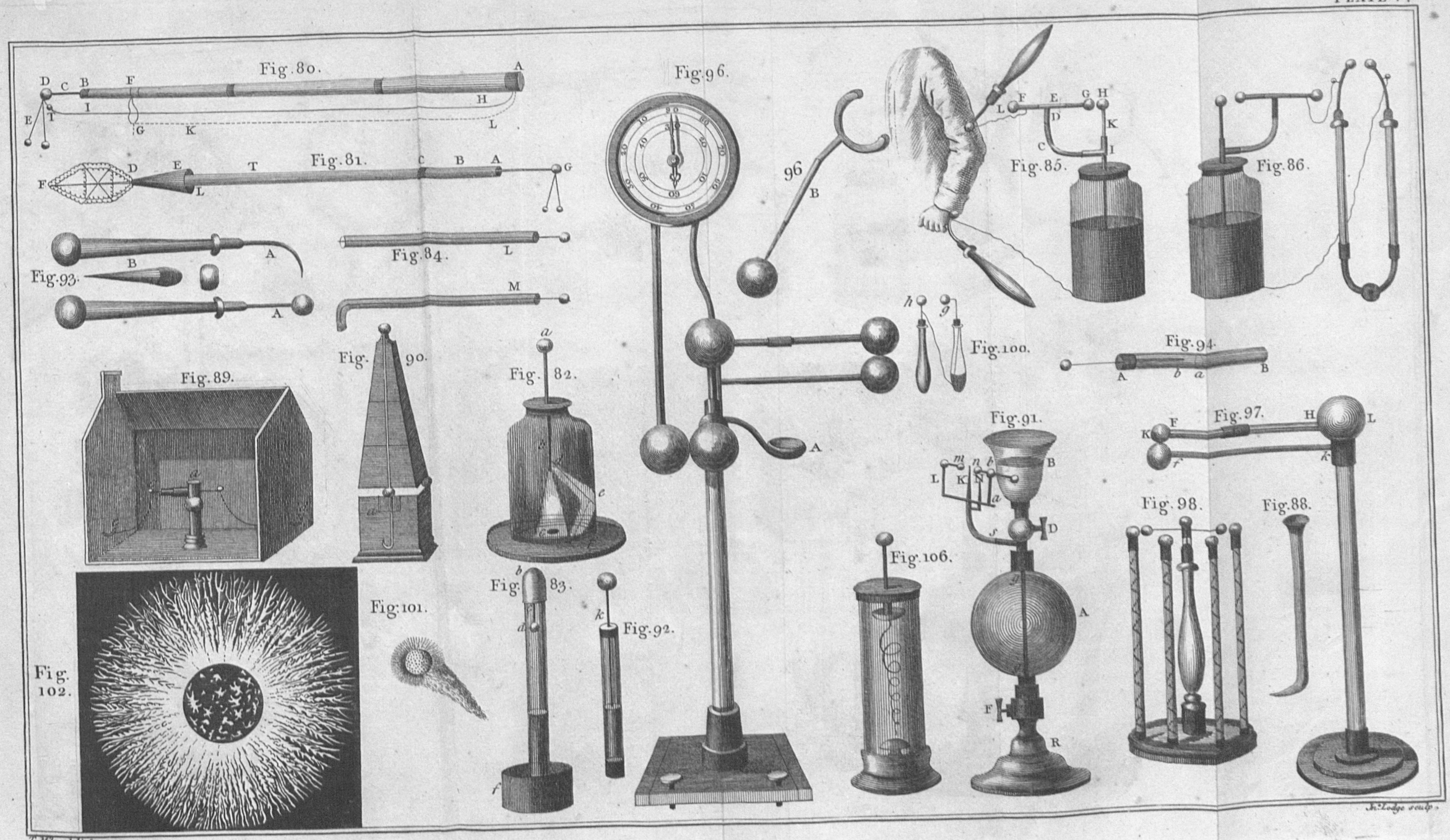
Fig. 80.
Fig. 81.
Fig. 84.
Fig. 93.
Fig. 96.
96
Fig. 85.
Fig. 86.
Fig. 100.
Fig. 94.
Fig. 89.
Fig. 90.
Fig. 82.
Fig. 91.
Fig. 97.
Fig. 98.
Fig. 88.
Fig. 106.
Fig. 101.
Fig. 83.
Fig. 92.
Fig. 102.
T. Milne delin.
N. Lodge sculp.