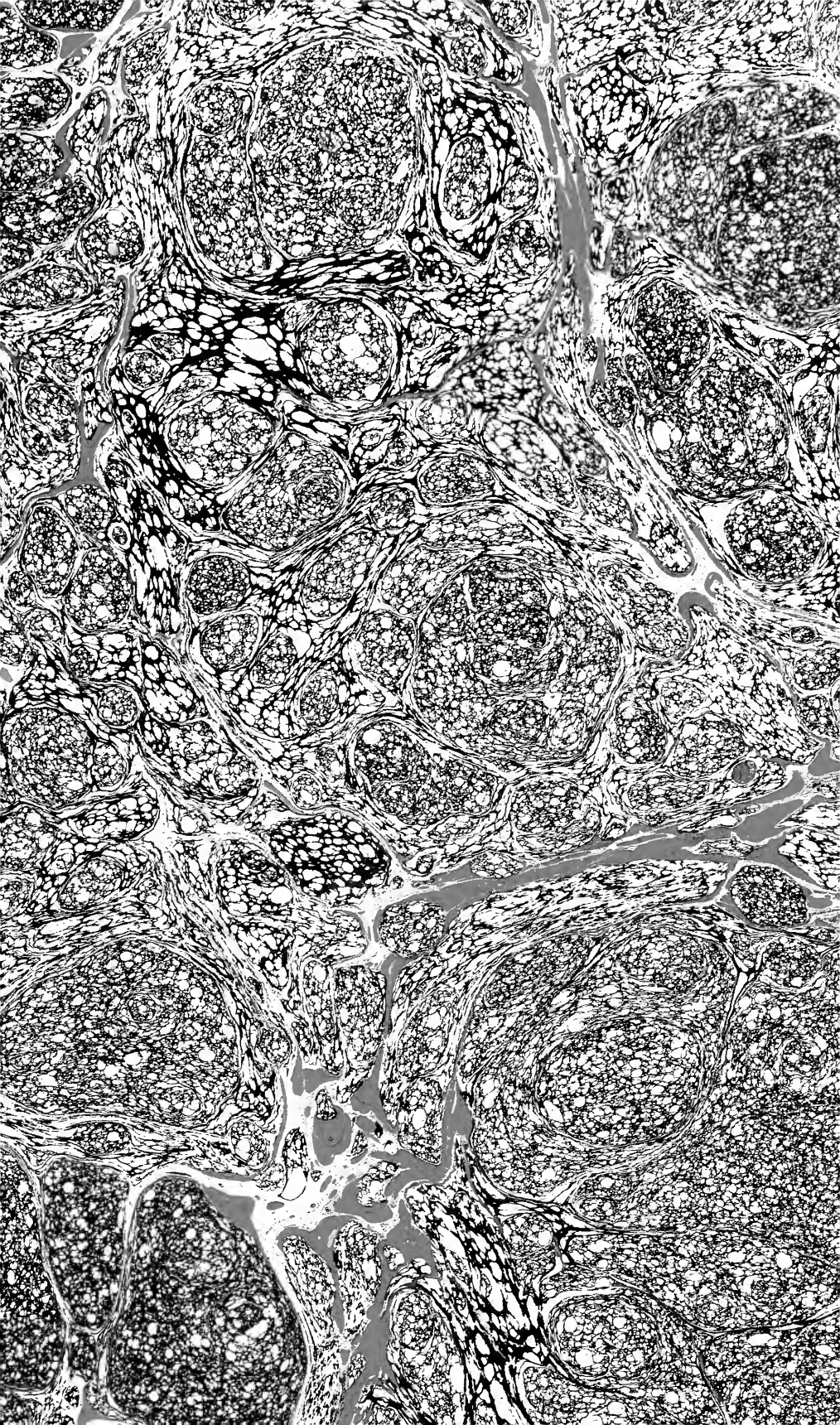




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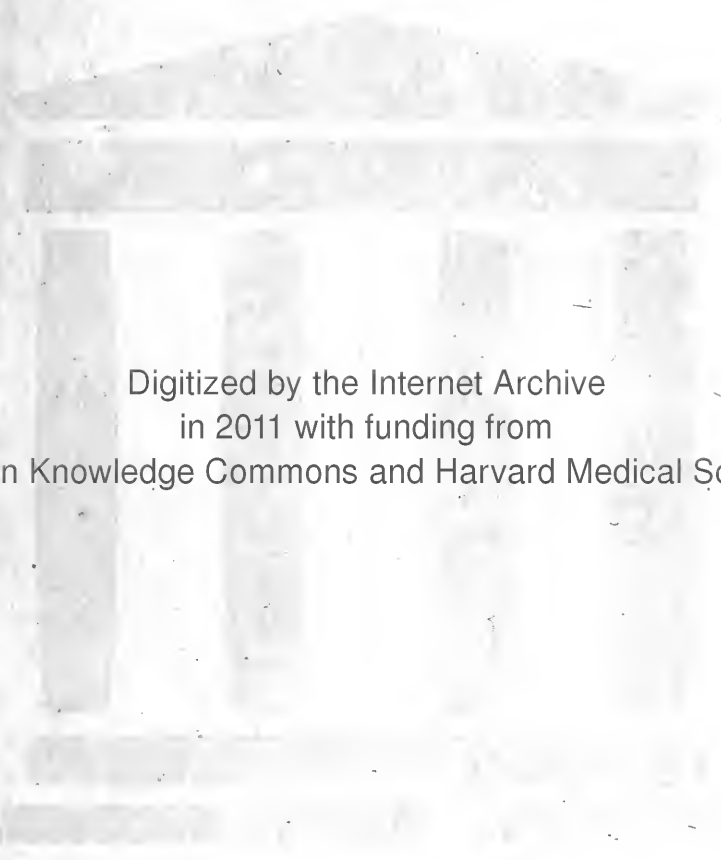
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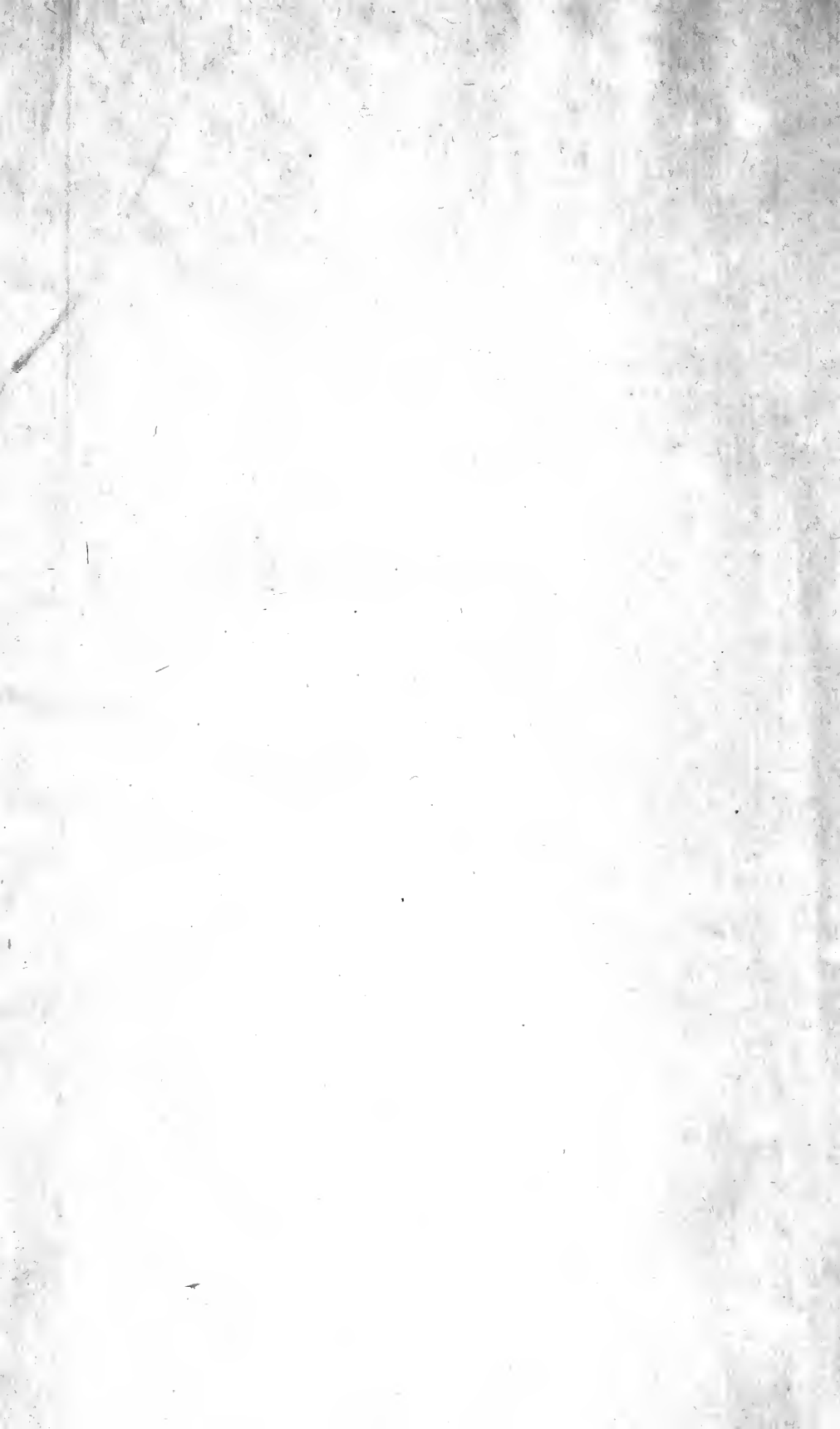
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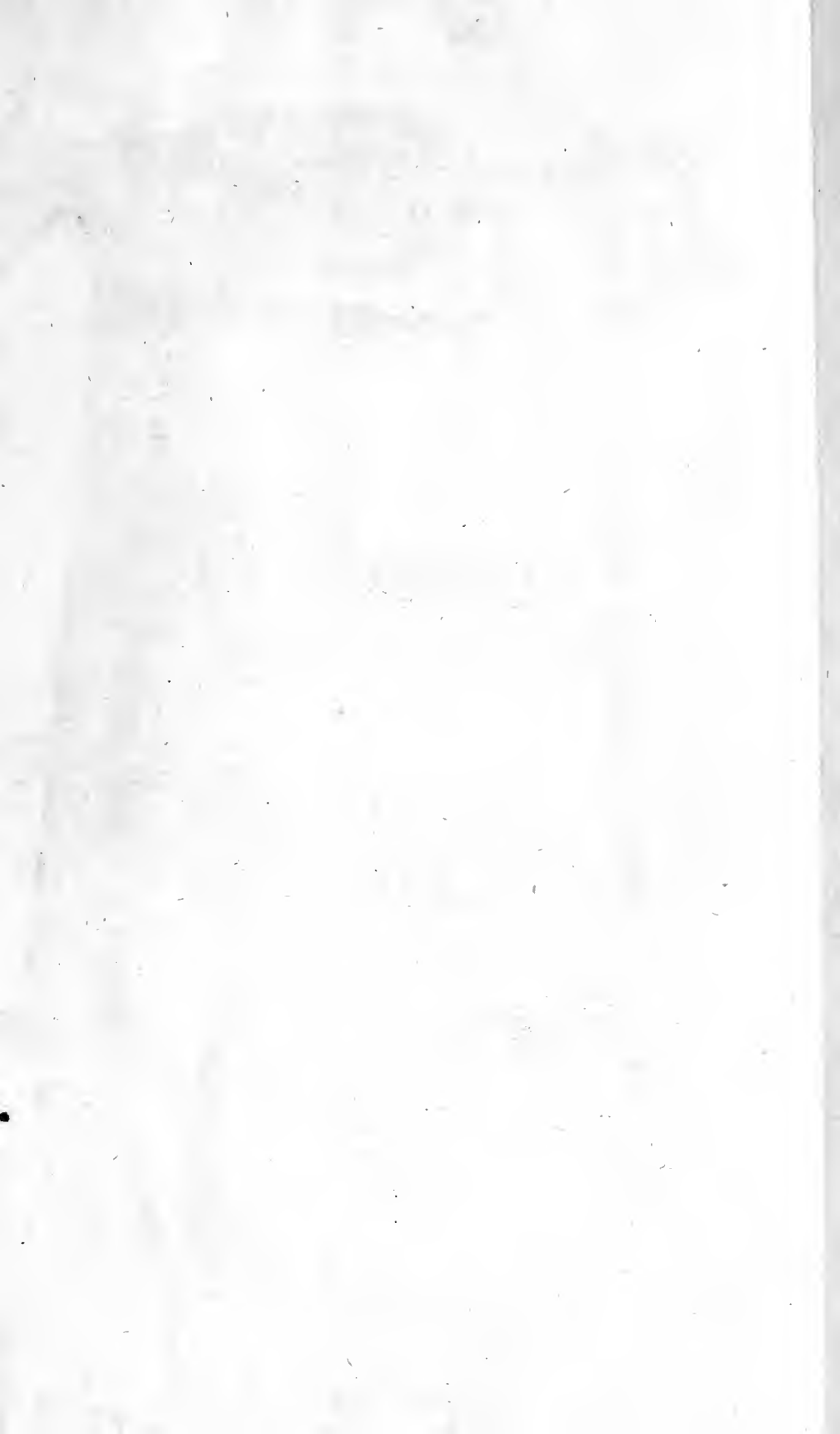
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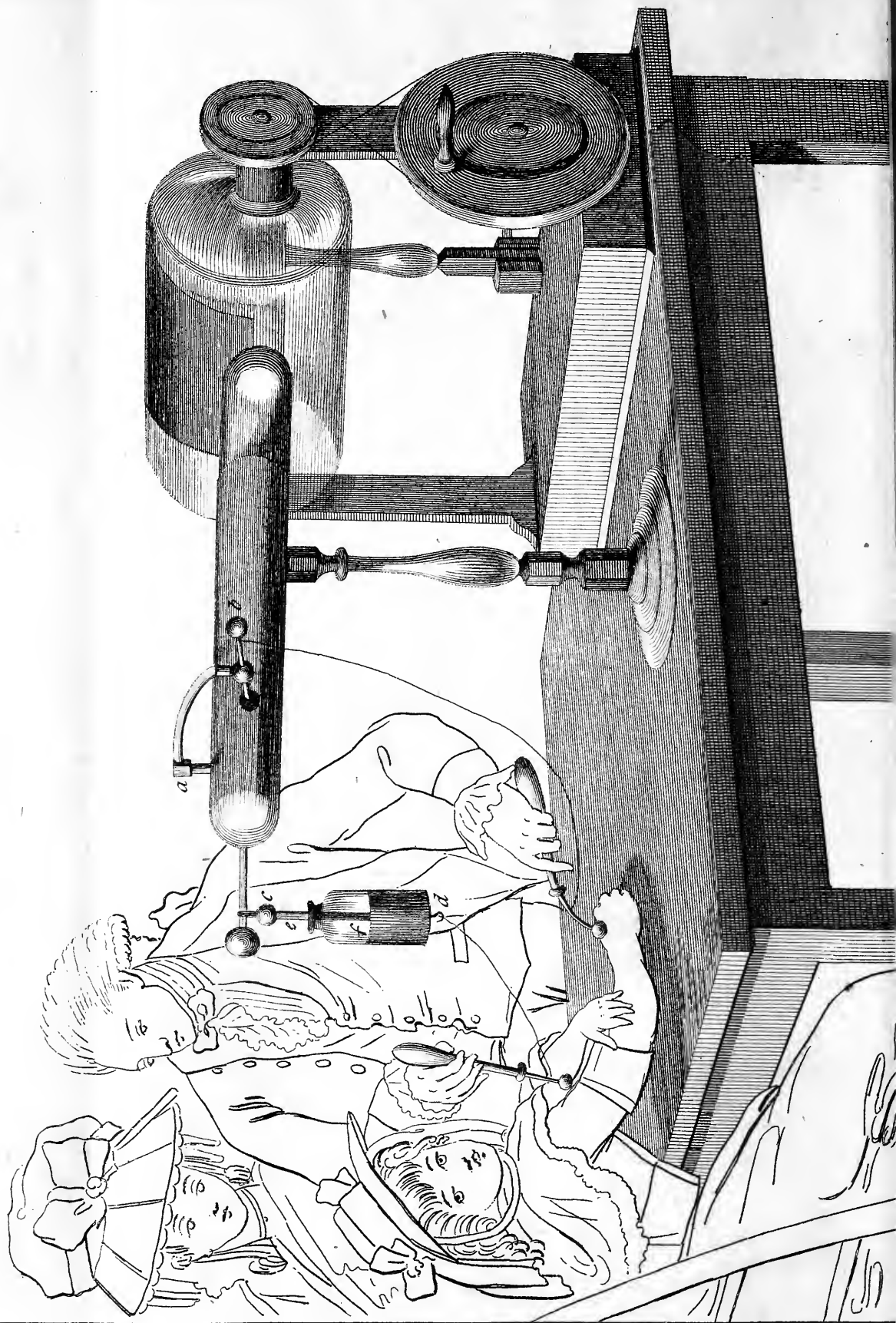




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AN
ESSAY ON ELECTRICITY,
EXPLAINING

The THEORY and PRACTICE of that useful SCIENCE;
and the mode of applying it
TO MEDICAL PURPOSES.

With an ESSAY on MAGNETISM.
THE SECOND EDITION.

Corrected and considerably enlarged

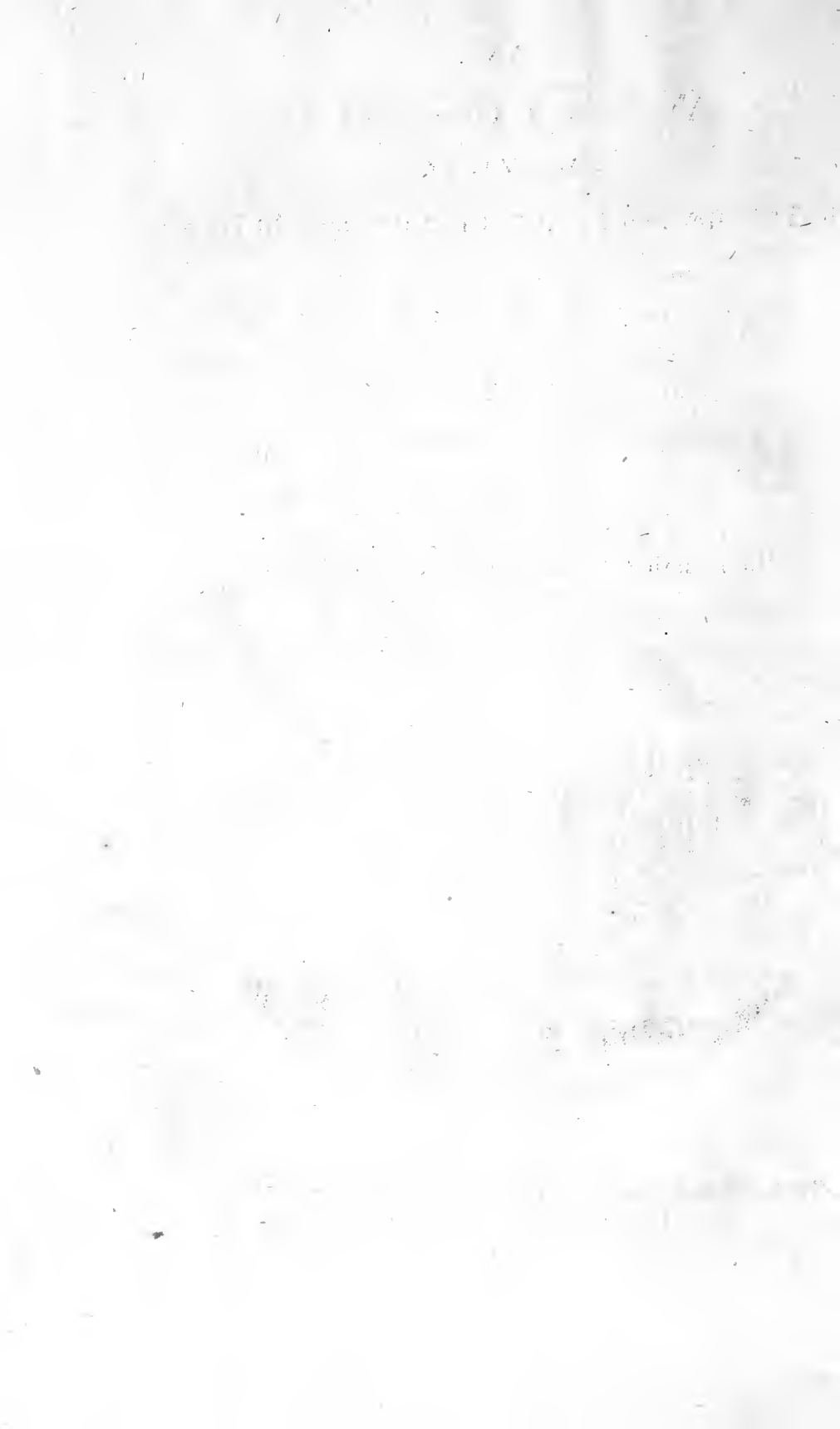
By GEORGE ADAMS,
Mathematical Instrument Maker to His Majesty.



L O N D O N :

*Printed at the Logographic Press for the Author, and sold by
him at Tycho Brahe's - Head, N^o 60 Fleet Street.*

1785.



ADVERTISEMENT.

BEING encouraged by the very rapid sale of the first edition of this work, to offer another to the public, I have endeavoured to render it more perfect by such additions and alterations, as either occurred to my own mind, or were suggested to me by others. The reader will find most of the chapters either enlarged by the addition of new matter, or improved by a different arrangement of the old; more particularly, the chapters on medical electricity and the Leyden phial.—The essay on magnetism is also considerably enlarged; for the present disposition and order of treat-

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ii A D V E R T I S E M E N T .

ing it I am indebted to the ingenious and kind hints of Dr. Lorimer. The additions are illustrated by two new plates, and an engraved frontispiece.

P R E-

P R E F A C E.

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

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

I have

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

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 wrote on this subject. I have used an unreserved freedom, in selecting from their works whatever I found to answer my purpose. I am particularly obliged to Sir Joseph Banks, for his politeness in lending me *Les Memoires de l'Academie de Berlin* for 1780, at a time when I could not procure them elsewhere.

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.

I beg leave to avail myself of this opportunity to acquaint the public, that I am now engaged in a work describing the mechanical parts of mathematical and philosophical learning, and explaining the various uses of the different instruments in their present state of improvement;
which,

which, I trust, will greatly tend to facilitate the attainment of knowledge, and accelerate its progress. For this purpose I have been at a considerable expence in collecting such materials as may enable me to offer to the public some essays on this subject, which I hope will not be found unworthy of its patronage, and which mean to publish with all convenient speed.

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E S S A Y
O N
E L E C T R I C I T Y.

C H A P. I.

OF ELECTRICITY IN GENERAL.

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 phœnomena of nature, should have remained so long in obscurity; for, comparatively speaking, its existence was not known to the ancients. They were not, indeed, altogether ignorant of the peculiar properties of those bodies that we now term electrics *PER SE*; nevertheless their knowledge was circumscribed, being confined to the observa-
B tion

tion only, of those phœnomena which nature presented to their senses, in the ordinary course of her operations; hence near two thousand years elapsed, before any addition was made to the little which was known to Theophrastus, and this branch of natural history remained uncultivated, till the happy period arrived, when the philosopher was emancipated from the chains of hypothetic reasoning, and the uncertainties of vague conjecture.

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

Electricity has been dignified in a peculiar manner, by engaging the attention of the philosophic historian; who, by delineating the gradual progress of its discoveries, describing the different theories which have been invented to account for its effects, and pointing out the *DESIDERATA* which still remain to be explored, has contributed in a high degree, to enlarge the boundaries of electricity, and to encrease the number of those who cultivate it.

Since the publication of Dr. Priestley's history, the electrical apparatus has been considerably augmented, and many new experiments
have

have been made. To describe the one, and to arrange the other, under such heads as will point out the connexion between the experiments and the received theory of electricity, was one of the principal views I had in composing this essay. I also wished to put into the hands of my customers a tract, which might enable them to use, with ease and satisfaction, the electrical machines and apparatus which I recommend.

As electricity is in its infancy, when considered as a science, its definitions and axioms cannot be stated with geometric accuracy. I shall, endeavour to avoid, as much as possible, the use of positive 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.

E X P E R I M E N T I.

Rub a dry glass tube with a piece of dry silk, 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.

E X P E R I M E N T II.

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

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

A certain quantity or natural share of the electric fluid, is supposed to be diffused 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

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 will then dart from the tube in a beautiful manner, and a snapping noise will be heard on the approach of any conductor.

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

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

E X P E R I M E N T 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

der will attract and repel light bodies, as forcibly as the excited electric itself.

E X P E R I M E N T I V.

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.

Those bodies which possess the power of transmitting electricity, are called CONDUCTORS AND NON-ELECTRICS.

Those substances, which are impervious to electricity, are called NON-CONDUCTORS, OR ELECTRICS.

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

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

From the third and fourth experiments we learn, that excited electrics will communicate the

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

E X P E R I M E N T 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.

E X P E R I M E N T VI.

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

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

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

Electricians have been engaged, by the discovery of the two foregoing distinctions to examine the electric properties of most bodies, to ascertain whether they possessed the positive or negative powers; by 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.

I *Stony Substances.*

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

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

Lime-

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 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 its substance; though it will pass over about three quarters of an inch of its surface to reach the finger that holds it, and it discharges the battery but slowly.

A piece of slate, such as is commonly used to write 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 plaister of Paris conducts very well, only the latter having a smoother surface takes a stronger spark.

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

A piece

A piece of Spanish chalk conducts much like marble.

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

2. *Saline Bodies.*

Oil of vitriol conducts very well.

The metallic salts in general conduct better than any neutrals.

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

Vitriolated tartar gives a small shock.

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

Volatile sal-ammoniac gives a small shock.

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

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

Salenitic salts conduct but poorly.

By

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, 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

uable 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 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.

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

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

The effluvia of flaming bodies.

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

E L E C T R I C B O D I E S.

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

per 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, remain among the electric desiderata; for, nothing more is ascertained, than, that the conducting power, in some measure, depends upon, or is governed by heat. Glafs, 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.

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 this body is subjected. He endeavours to shew, that the principal changes which take place in any substance from an increase of heat; are an augmentation in the size of its pores, and an increase of velocity in the igneous particles contained in, and acting on, that body. He then proves, that the last circumstance does not occasion the alteration in the electric properties; and

and infers, agreeable to the system of Mr. Euler, that the principal difference between conductors and non-conductors of electricity consists in the size of the pores of the constituent parts of the body.

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.

* 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.

Hare's skin	<table> <tbody> <tr> <td>Positive</td> <td>Metals, silk, loadstone, leather, hand, paper, baked wood.</td> </tr> <tr> <td>Negative</td> <td>Other finer furs.</td> </tr> </tbody> </table>	Positive	Metals, silk, loadstone, leather, hand, paper, baked wood.	Negative	Other finer furs.
Positive	Metals, silk, loadstone, leather, hand, paper, baked wood.				
Negative	Other finer furs.				
White silk	<table> <tbody> <tr> <td>Positive</td> <td>Black silk, metals, black cloth.</td> </tr> <tr> <td>Negative</td> <td>Paper, hand, hair, weasel's skin.</td> </tr> </tbody> </table>	Positive	Black silk, metals, black cloth.	Negative	Paper, hand, hair, weasel's skin.
Positive	Black silk, metals, black cloth.				
Negative	Paper, hand, hair, weasel's skin.				
Black silk	<table> <tbody> <tr> <td>Positive</td> <td>Sealing wax.</td> </tr> <tr> <td>Negative</td> <td>Hare's weasel's, and ferret's skins, loadstone, brass, silver, iron, hand.</td> </tr> </tbody> </table>	Positive	Sealing wax.	Negative	Hare's weasel's, and ferret's skins, loadstone, brass, silver, iron, hand.
Positive	Sealing wax.				
Negative	Hare's weasel's, and ferret's skins, loadstone, brass, silver, iron, hand.				
Sealing wax	<table> <tbody> <tr> <td>Positive</td> <td>Metals.</td> </tr> <tr> <td>Negative</td> <td>Hare's, weasel's, and ferret's skins, hand, leather, woollen cloth, paper.</td> </tr> </tbody> </table>	Positive	Metals.	Negative	Hare's, weasel's, and ferret's skins, hand, leather, woollen cloth, paper.
Positive	Metals.				
Negative	Hare's, weasel's, and ferret's skins, hand, leather, woollen cloth, paper.				
Baked wood	<table> <tbody> <tr> <td>Positive</td> <td>Silk.</td> </tr> <tr> <td>Negative</td> <td>Flannel.</td> </tr> </tbody> </table>	Positive	Silk.	Negative	Flannel.
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

be black, it will never become positive, unless B be black likewise. With pieces of glass the effect is contrary; for, if they are both equal, the piece A, which is drawn across the piece B, becomes negative; and B, which suffers the greatest friction, becomes positive. Heating by fire produces the same effect as the greater friction. If one piece of glass be thicker than the other, the former becomes positive, the latter negative. Coloured glass, even when heated, becomes negative, if rubbed with common white glass. If a piece of blue glass is rubbed against a green one, the blue glass becomes strongly positive, &c.——Bergman, Swedish Tran. 1765.

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

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

same same effect is produced as with living hair.
Wilke Swed. Tran. 1769.

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

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

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

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

It may be proper to observe here, that the two classes of electrics and non-electrics are not so strongly marked by nature as to enable the electrician to arrange every substance with propriety: hence the same substance has been
placed

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 inaccurate, since every substance is in a certain degree a conductor of this fluid, tho' some resist its passage more than others.

C H A P II.

OF THE ELECTRICAL MACHINE; WITH DIRECTIONS FOR EXCITING IT.

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

That the operator may proceed 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.

The

1. The electric, as the glass cylinder.
2. The mechanical contrivances by which the electric is put in motion.
3. The cushion and its appendages.
4. The conductor or conductors.

Fig. 1 and 2, Plate I. 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 fig. 2. is turned round by means of the two wheels a b, c d, which act on each other by a catgut band, part of which is seen at e and f.

The cylinder of the machine which is represented in fig. 1; is put in motion by a simple winch, which is less complicated than the other, and not so liable to be out of order. Most 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 a moderate increase of velocity in the cylinder augments the momentum of the electric fluid, and produces a greater quantity of it in the same time, which prevents its being absorbed by the cushion. And farther, when the machine is fixed to a table, the position of the lower

multiplying wheel is more advantageous than that of the winch, and may be turned with the right hand.

As the two machines, which are represented in fig. 1 and 2, plate I. are nearly similar, the same letters of reference are used in describing them.

Fig. 1 and 2. A B C represents the bottom board of the machine.

D, 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 a simple winch is fitted, as in fig. 1, or a pulley, as in fig. 2.

The axis of the other cap runs in a small hole which is fitted into 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 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 board.

g h i A piece of silk that comes from the under edge of the cushion, and passes over the cylinder, but between it and the cushion, proceeding regularly till it nearly meets the collecting points of the conductor.

Near the top of the glass pillar O P is an arm of wood, to support a conductor connected with the cushion, which is called a negative conductor. In both figures this conductor is supposed to be fixed close to the cushion, and to lie parallel to the glass cylinder. In fig. 1 it is brought forwards, or placed too near the handle, in order that more of it may be in sight, as at R S; in fig. 2, the end R S only is seen.

Y Z Fig. 1 and 2, 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 fig. 1, this conductor is placed in a direction parallel to the glass cylinder; in fig. 2, it stands at right angles to the cylinder; it may be placed in either position occasionally, as is most convenient to the operator. It is most convenient to have both conductors fixed on separate stands, unconnected with the machine, that their position may be

more easily accommodated to the peculiar circumstances of different experiments.

DIRECTIONS FOR KEEPING THE MACHINE IN
ORDER.

Before the electrical machine is put in motion, examine those parts which are liable to wear from the friction of one surface against another; or to be injured by dirt, that may insinuate itself between the rubbing surfaces: as the axes which work in the wooden supports D, E, and the axis of the large wheel c d, fig. 2.

If any grating or disagreeable noise is heard, the place from whence it proceeds must be discovered, then 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.

Examine the screws that belong to the frame, and if they are loose, tighten them.

The different working parts of the machine having been thus examined, and put in order, the glass cylinder, and the pillars which support the cushion and conductor, should then be carefully wiped, to free them from the moisture which glass attracts from the air, being particularly

larly attentive to leave no moisture on the ends of the cylinder, as any damp on these carries off the electric fluid.

Glass pillars have been sometimes used to support the cylinder, but they can be of no use, unless the foregoing circumstance is attended to; and if that is observed they are superfluous.

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

Rub the glass cylinder first with a clean, coarse, dry, warm cloth, or a piece of wash leather, and then with a piece of dry, warm, soft silk; do the same to all the glass insulating pillars of the machine and apparatus; these pillars must be rubbed more lightly than the cylinder, because they are varnished.

A heated iron is sometimes placed on the foot of the conductor, to evaporate the moisture which would injure the experiments.

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

In order to find out an effectual mode of exciting powerfully an electrical machine, it is necessary to frame an 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, those machines which have passed through my hands.

It appears to me, 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. 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. 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

every conducting substance that is near it, if any amalgama 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 amalgama 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 amalgama was spread over the whole of the flap; the cushion was then put in its place, and the loose flap of leather doubled down, or rather turned in, more or less, till by successive experiments the situation was discovered which produced the greatest effect; for, by this means, the quantity of amalgama 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

shion, and place it in such manner that it might be easily raised or lowered.

To find the line of contact formed between the cylinder and cushion; place a line of whitening which has been previously dissolved in spirits of wine, on the cylinder, on turning this round the whitening is deposited on the cushion, and marks the places which bear against the cylinder. The amalgam is to be put on those parts only, which are thus marked by the whitening: or, this line may be ascertained, by observing the parts of the cushion which gather the dust from the cylinder, and laying the amalgam on those parts.

The line of contact being found and the amalgam placed on it; the cylinder is to be rubbed with a piece of leather which is covered with amalgam; this renders the contact between the cylinder and cushion more perfect, by filling the smaller pores of the glass with amalgam, and depositing the superfluous particles on the cushion; it is also probable that the amalgama, thus deposited on the surface of the glass, forms a continued series of conducting particles, which carry the fire to the prime conductor, and, under certain circumstances, back again to the cushion. When the cylinder is
rubbed

rubbed with the amalgamated leather, that part of the oil, or black filk, which lies above the cushion, is to be turned back, and if, by accident, any particles of amalgama 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 then take off the cushion and dry the filk.

If the electricity of the cylinder grows less powerful, it is easily renewed by turning back the filk which lies over it, and then 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 amalgama, 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.

EXPERIMENT VII.

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

towards these, and they will disappear. 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; for the air not only resists the emission of the fluid, but also dissipates what is collected by means of the conducting substances, which are continually floating in it.

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

When the zinc amalgam is used, the silk will sometimes adhere so strongly to the cylinder as to render it very difficult to turn; to obviate this, wipe the silk perfectly clean, and then rub it over
with

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 sparkle round the cylinder, and throw out many beautiful brushes of light.

Two kinds of amalgama are much in request at present. One is made of quicksilver five parts, zink one part, melted together with a small quantity of bees-wax: the other is the aurum musivum of the shops. I find it difficult, after many trials, to say which of these act the best. To make the amalgam adhere closely to silk, it is necessary to grease this, then wipe off as much of the grease as you can, and afterwards 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 the bodies connected with it.

E X P E R I M E N T V I I I .

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.

Every electrical machine ought to be furnished with an insulated cushion and two prime conductors, one for positive, the other for negative electricity; as by these, either electricity is produced at pleasure, a greater number of experiments may be performed, and the properties of the electric fluid more easily explained.

E X P E R I M E N T I X .

Put the machine in action, connect the cushion by a chain with the ground, and those bodies which communicate with the positive conductor will be electrified positively. Connect the positive conductor with the earth by a chain, take off the chain from the cushion, and those bodies which communicate with the negative conductor will be electrified negatively.

E X P E R I M E N T X .

Connect the positive conductor by a chain with the table; turn the cylinder, and the cushion

cushion will be found to be negatively electrified. Take the chain off from the positive conductor, and both will exhibit signs of electricity; but any electrified body which is attracted by the one, will be repelled by the other. If they are brought sufficiently near to each other, sparks will pass between them, and they will act on each other stronger than on any other bodies. If they are connected together, the electricity of the one will destroy that of the other; for though it seems to proceed from the cushion to the conductor, the two, when thus conjoined, will exhibit no signs of electricity, because the fire is continually circulating from one to the other, and is kept always in the same state.

We see, by this experiment, that electric appearances are produced both in the electric which is excited, and the substance by which it is excited, provided that substance be insulated; but their electric powers are directly reverse of each other, and may be distinguished by opposite effects.

E X P E R I M E N T X I.

If the cushion and the conductor are both insulated, it is observed, that the less electric
D fluid

fluid is obtained, the more perfect the insulation is made.

The moisture which is at all times floating in the air, together with the small points, from which it is impossible totally to free the cushion, do not permit it to be perfectly insulated, so as to afford no supply of electric matter to the cushion.

If the air, and other parts of the apparatus, are very dry, little or no electricity will be produced in the above-mentioned circumstances.

From this experiment it is inferred, that the electric powers do not exist in the electrics themselves, but are produced from the earth by the excitation of electrics; or that the electric matter on the prime conductor is not produced by the friction of the cylinder against the cushion, but is collected by that operation from it, and from those bodies which are connected with it.

As Dr. Franklin seems to have suggested this idea first, that the electric fluid is collected from the earth, I have subjoined his own account of the experiment which led him to this conclusion.

EXPERIMENT XII.

Let one person stand on wax and rub a glass tube, and let another person on wax 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 the 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 discover ANY ELECTRICITY.

These appearances he accounts for thus: he supposes 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 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 : hence we say, that B is electrified positively, A negatively.

As those experiments have been described, which are the foundation of our present knowledge in electricity, I hope it will not be deemed improper to introduce in this place those hypotheses which have been built on them.

Dr. Franklin's hypothesis depends on, and may be reduced to, the following principles.

1. That

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

2. That the operations of electricity depend on one fluid *SUI GENERIS*, extremely subtil and elastic.

3. Glass and other electric substances though they contain a great deal of electric matter, are *IMPERMEABLE* to it.

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

5. That conducting substances are permeable to the electric matter through their whole substance, and do not conduct merely over their surface.

6. Positive electricity is when a body has more than its natural share of the electric fluid, and negative electricity when it has less than its natural share.

The following hypothesis is extracted from the analysis of a course of lectures by Mr. Atwood, to which, and Mr. Eeles's philosophical essays, I must refer the reader for a fuller account of it; in the course of this essay many observations will occur, which tend to confirm this, and refute the foregoing hypothesis.

HYPOTHESIS,

1. That two electric powers exist together in all bodies.
2. Since they counteract each other when united, they can be made 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 powers cannot be separated in electric substances.
5. The two electricities attract each other strongly through the substance of electrics.
6. Electric substances are impervious to the two electricities.
7. Either power, when applied to an un-electrified body, repels the power of the same sort, and attracts the contrary power.

A DESCRIPTION OF SOME PARTS OF THE ELECTRIC APPARATUS WHICH COULD NOT BE REGULARLY INTRODUCED IN THE BODY OF THE WORK.

Fig. 1. Plate II. represents a common discharging rod; it is generally made of brass wire, with a ball at each of its ends. To discharge

charge a Leyden bottle with it, hold the semi-circular part in the hand, place one ball of the discharging rod on the coating of the phial, then bring the other to touch the knob of the wire which communicates with the inside when an explosion will ensue, and the phial will be discharged.

Fig. 2. Plate II. is a joined discharging rod with a glass handle, the legs of which may be moved and set to any given distance from each other by means of the joint C; the extremities of the legs are pointed, the points enter into the balls a, b, which screw on the legs, and from which they may be unscrewed at pleasure; so that either the balls or the points may be used as occasion requires.

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. When the universal discharger is made on a large scale, it is a convenient apparatus to enable a person to electrify himself; see fig. 87.

AB. 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, ET, EF; 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: GH 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 GH 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. Kinnerfley's electrical air thermometer; a b is a glass tube, on each end of which a brass cup 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.

Electricians have long wished for an instrument which would ascertain, in an exact and invariable manner, the degree of electricity excited when any experiment is made. For this purpose a great many contrivances have been proposed and executed, which, upon trial, are all found to be very defective.

An electrometer ought to have the following properties.

1. It should be simple in its construction, and not composed of many parts.

2. It should not be affected by the variations of the atmosphere.

3. It should indicate small as well as large degrees of electricity.

4. Not to be adjusted to any fixed measure.

5. The electric power should be expressed by a fixed and invariable force, as that of gravity.

6. That

6. That the observer be enabled to read off the divisions at a distance, which will prevent his weakening the influence of the electric powers.

Plate II. Fig. 6, represents the quadrant electrometer the most useful instrument of the kind yet discovered, as well for measuring the degree of electricity of any body, as to ascertain the quantity of a charge before an explosion; and to discover the exact time the electricity of a jar changes, when without making an explosion, it is discharged by giving it a quantity of the contrary electricity. The pillar LM is generally made of wood, the graduated arch NOP of ivory, the rod RS is made of very light wood, with a pith ball at the extremity; it turns upon the centre of the semicircle, so as always to keep near its surface; the extremity of the stem LM may either be fitted to the conductor or the knob of a jar. When the apparatus is electrified, the rod is repelled by the stem, and moves along the graduated arch of the semicircle, so as to mark the degree to which the conductor is electrified, or the height to which the charge of the jar is advanced.

Beccaria recommends fixing the index between two semicircles, because when it is placed

placed over one only, the electricity of this repels and counteracts the motion of the index. Other improvements and variations have been made in this instrument, which will be described hereafter.

Plate II. Fig. 9, is an electrometer which was contrived many years since by Mr. Townsend, to ascertain the real force of the electric explosion. *a b* is a small ivory plate, *c* a loose cone of ivory to be placed on the plate *a b*, *e f g*, a circle which turns freely on two centres, an arm, *d*, of wood proceeds from this circle and lyes on the cone of ivory. The discharge is made to pass under the cone which throws up the arm *d*, the elevation of which is marked by the index *h*; a piece of silk string is fixed at one end to the bottom board at *i*, and passes over the wheel, a weight *k* is tied to the other end to regulate the friction of the circle *e f g*.

Fig. 8 is an insulating stool; the feet are of glass. When it is used, the insulation will be rendered more perfect by placing a sheet of paper well dried under the feet of the stool.

C H A P. III.

THE PROPERTIES OF ELECTRIC ATTRACTION
AND REPULSION, ILLUSTRATED BY EXPERI-
MENTS ON LIGHT BODIES.

NATURAL philosophers were originally incited to consider the nature of electricity from its strong attractive and repulsive powers. The phœnomena 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 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*
" font

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

2. Bodies that are electrified positively repel each other.

3. Bodies electrified negatively repel each other.

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

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

“ font à cent milles lieues, ou à cent milliemes parties,
 “ d’un ligne de distance l’un de l’autre, sans aucune com-
 “ munication materielle entrelles, et à l’ocasion de l’une
 “ l’autre se mouvroit !!” De Luc. Lettres Physiques, &c.

6. Those

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 immersed in an electric atmosphere always become possessed of an electricity contrary to that of the body in whose atmosphere they are immersed.

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

These experiments may all be made with a small and portable apparatus; consisting generally of two 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 pith balls suspended on linen threads, as I, K, fit upon each tube by means of a small
brass

brass ring; these tubes, with a piece of sealing wax or a glass tube, are sufficient to illustrate the greater part of the experiments in this chapter, as well as some of the principal phenomena in electricity.

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

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

EXPERIMENT XIII.

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

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

tively 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.

E X P E R I M E N T X I V .

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

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

as

as it continues of the same force, and acts at the same distance.

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

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

E X P E R I M E N T X V.

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.

E X P E R I M E N T X V I.

Electrify the tubes A and B, fig. 27, equally and with the same power, put the ends of the

E tubes

tubes together, and the divergence of the balls will not be altered.

EXPERIMENT XVII.

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

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

EXPERIMENT XVIII.

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 electrical 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 XIX.

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, and are attracted by all other matter. Therefore when any body is immersed 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 immersed 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 exert any sensible action.

E X P E R I M E N T XX.

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.

E X P E R I M E N T XXI.

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 XXII.

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

EXPERIMENT XXIII.

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

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elec-

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

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 XXIV.

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

EXPERIMENT XXV.

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

* Ibid. p. 8.

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

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

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

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

It

* Ibid, p. 18.

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

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

EXPERIMENT XXVI.

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

earth in a hot day, or at any time near a body strongly heated,

EXPERIMENTS ON THE ATTRACTION AND REPULSION OF EXCITED SILK RIBBON.

EXPERIMENT XXVII.

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 XXVIII.

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 XXIX.

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

EXPERIMENT XXX.

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 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 XXXI.

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

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 XXXII.

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 XXXIII.

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

EXPERIMENT XXXIV.

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

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 XXXV.

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

The following very curious observations and experiments were made by Mr. Symmer. He had been accustomed to wear two pair of silk stockings, a black and a white, when these were pulled off both together no signs of electricity appeared; but, on pulling off the black ones from the white, he heard a snapping or cracking noise, and in the dark perceived sparks between them. To produce this and the

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 intire 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 a black stocking are presented to each other they are mutually attracted, and rush together, if permitted, with great violence. As they approach the inflation gradually subsides, and their attraction of foreign objects diminishes, but their attraction of one another increases; when they actually meet, they become flat and joined close together, like so many folds of silk; when separated again, their electric virtue does not seem 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

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

C H A P. IV.

ENTERTAINING EXPERIMENTS BY THE ATTRAC-
TION 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.

E X P E R I M E N T. XXXVI.

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

Present a metallic point, the finger, or any other conducting substance to the feathers, the downy parts thereof will immediately collapse,
the

the divergence of the feathers will cease, and they will approach each other, and cling round the non-electric body.

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

EXPERIMENT XXXVII.

Fix the end C of the wire CD, Fig. 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 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 XXXVIII.

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

EXPERIMENT XXXIX.

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

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

EXPERIMENT XL.

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 XLI.

Remove the under plate and stand, hold in its stead, by one corner, a pane of glass, which has previously been made very clean and dry; now, as glass does not transmit electricity, 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;

* Philosophical Essays. Preface, page 25.

“ dry; this will therefore ascend to the upper
 “ plate and remain there. Reverse the expe-
 “ riment; dry the feet and wet the head, and
 “ the images will fix themselves to the lower
 “ plate. If the image retains so much more of
 “ the attracted power as will balance against
 “ its weight, than there is of the contrary
 “ power which proceeds from the conductor,
 “ the image will be suspended between the two
 “ plates.

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

EXPERIMENT XLII.

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 in-
 to 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 XLIII.

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 XLIV.

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 XLV.

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

fied conductor, and when the leaf brass is within its atmosphere, let it go; it will then fix itself to the conductor by the apex of its obtuse angle, and, from its continual wavering motion, will appear to be animated.

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

EXPERIMENT XLVI.

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

EXPERIMENT XLVII.

Fig. 17 represents a small set of bells, the two exterior ones are connected to the wire *V Y*,

by a brass chain, the middle bell and the clappers are suspended on silk.

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

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

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

Fig. 19 represents another kind. In this the clapper is suspended from the fly b c d, the axis of the fly rests in a small hole on the top of the glass pillar e f, the upper part of the axis moves

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 its stead near the cylinder; when this is in action, it will cause the fly to turn round, the clapper will strike each bell in rotation, and thus produce a pleasing and harmonious sound.

EXPERIMENT XLVIII.

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 XLIX.

Bring a downy feather or lock of cotton near the end of an excited tube, or the knob of a charged Leyden phial, the feather will at first fly towards the tube, but when it is saturated with the electric matter, it will recede from it, and may be driven about the room by the excited

cited tube, till it touches some non-conductor, to which it can impart its electricity. The same side of the feather is always turned towards the tube; because the electricity acquired by the feather, is forced by the action of the tube, to that side which is farthest from it, which is therefore repelled.

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

EXPERIMENT L.

Put a pointed 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

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.

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

EXPERIMENT LI.

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

EXPERIMENT LII.

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

To account for any of the phenomena of electric attraction and repulsion, is very difficult, but more so to shew why bodies, which
are

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 or 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, 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

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

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 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,

* Encyclopædia Britannica, p. 2683.

† Ibid, p. 2699.

there is also a vibratory motion, but the force is directed inwards. Now let us suppose a body positively electrified, suspended by a small thread, at a distance from any other, the vibratory motion being kept up by an equal pressure on all sides, the body is neither moved to one side nor another; but when a negatively electrified body is brought near, the force of the vibration being directed outwards in the one, and inwards in the other, the pressure of the fluid in the intermediate space between them is greatly lessened, and consequently the pressure on the other side drives them both together, and they are said to attract each other. If a body electrified positively, is brought near the first, the force of the vibrations are 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

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

From several experiments of Beccarias, 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. Cavallos. A pith ball electrometer was suspended within a receiver of an air pump, by its brass cap; this was then electrified; the balls diverged a little when the air was only rarified 100 times; when it was rarified 300 times,

times, the repulsion was scarce discernible: when the rarification was greater, they did not diverge at all; and that, whether a small or large quantity of electricity was communicated to the cap.*

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

CHAP. V.

OF THE ELECTRIC SPARK.

EXPERIMENT LIII.

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

The experiments in the foregoing chapter show, 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 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 straight; but when it is strong, and capable of striking at a greater distance, it assumes a crooked or zig-zag direction; and this, probably, because the more fluid electric matter has to pass with great rapid-

ity through the denser and less fluid atmosphere, which reciprocally act upon each other.

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

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

electric fluid, and the pressure of one part of this matter upon another. This latter pressure must be very great, if the particles of the electric fluid are in contact, or act immediately one on the other throughout the wide immensity of space.

The electric spark appears of a different colour, according to its density: when it is rare, it appears of a 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 its entrance and exit.

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

E X P E R I M E N T L I V .

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 LV.

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 forgoing 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 LVI.

Mr. Hauxsbee 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

was at least an eighth part of an inch thick ; yet, even in those places, the shape and figure of his hand were as distinguishable as any where else.

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

EXPERIMENT LVII.

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 LVIII.

Connect one end of a chain with the outside of a charged jar, let the other end lye on the
G 4 table,

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. This experiment was communicated to me by Mr. Haas, the inventor of an improved air pump.

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 LIX.

The sparks taken over a piece of silver leather, appear of a green colour

EXPERIMENT LX.

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

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 spark taken from the conductor; for if there was no break in the tin-foil, the electric fire would pass off unperceived.

E X P E R I M E N T L X I .

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

E X P E R I M E N T L X I I .

To take the electric spark with a metal point, screw a pointed brass wire into one end of a spiral tube

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.

E X P E R I M E N T L X I I I .

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.

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

Let

E X P E R I M E N T L X I V .

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.

E X P E R I M E N T L X V .

To fire spirits of wine with the electric spark, heat the ladle, I, fig. 33, then pour a small quantity of spirit of wine into it, and fix it by its handle

handle to the end of the prime conductor; or fire the spirits, and blow them out a few minutes before the experiment is made; take a spark through the middle of the ladle with a brass ball, and the spirits will be fired by it.

Or let a person, standing on an 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.

E X P E R I M E N T L X V I .

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 immerse 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 LXVII.

The spirits cannot be kindled by the insulated person, because as the electric 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 ever set spirits on fire.

If oil of turpentine is set on fire in a vessel which is placed on the conductor, and the smoke is received on a plate, held by a person standing on an insulated stool, he will be electrified thereby, and enabled to fire spirits of wine, &c. If the insulated person holds a brass wire at the top of the flame of burning spirits of wine which is connected with the conductor, he will also become electrified. Hence we find that either smoke or flame conducts the electrical fluid.

Mr. Volta has succeeded in obtaining undoubted signs of electricity from the simple evaporation of water, and from various chemical effervescences.

EXPERIMENT LXVIII.

Insulate a small crucible, containing three or four lighted coals, throw a spoonful of water on the
the

the coals, and in a short space of time, an electrometer, which communicates with the coals by means of a wire, will diverge with negative electricity.

From hence it would seem, that the vapour of water, and, in general, those parts of a body that are separated by volatilization, carry away an additional quantity of electric fluid, as well as of elementary heat; and that the body, from which those volatile parts have been separated, remains both cooled and electrified negatively; and, that those which are resolved into a volatile elastic fluid, have their capacity for holding common fire, and the electric fluid augmented.

OF INFLAMMABLE AIR AND THE PISTOL FOR INFLAMMABLE AIR.

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

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 basin T into the neck of the bottle K, which is filled with water, and inverted in the basin, the bottle K must be supported during the operation: in a little time the mixture will effervesce, and emit a fluid which will pass through the bent tube, go into the bottle K, and at last fill it totally, expelling the water; the bottle is then to be removed, and corked as expeditiously as possible.

Fig. 39. represents a brass pistol for inflammable air; a b is a 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

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 glafs funnel.
2. A small glafs 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 glafs tube, and to which the spark is to be given,

is fitted into the side of the pistol. At the end b of the pistol is a male screw which fits the lower end of the stop cock.

6. A box with iron filings.

7. A small measure which will hold the proper quantity of iron filings.

8. A brass tube and hollow flyer ; the lower end of the brass tube fits the stop cock.

Soak the bladder in water which is lukewarm, in order to soften it ; and then render it pliable, by blowing air into it and squeezing it out again. After this screw the conical pipe with the cork into the lower end of the stop cock, and it is ready for use. Then take a common quart wine bottle, and put into it a little hot water, to warm it. Pour as much oil of vitriol into the tumbler, as will about half fill it, and mix this in another tumbler with about three times the quantity of cold water. Throw the warm water out of the bottle, and put a measure of iron filings into it, then pour the diluted vitriol through the glass funnel upon the iron filings. As soon as the effervescence begins, put the cork with its pipe into the neck of the bottle, and the inflammable air which is generated by the mixture, will enter into and gradually swell the bladder. When this is full, shut the stop cock, and remove the bladder from the bottle.

The bladder being thus filled, screw the bottom of the 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 its capacity, and put the cork immediately into the muzzle of the pistol. To form a circle of fire with inflammable air, fill the bladder as before, unscrew the conical tube from the stop cock, and screw the brass fly in its place, open the cock, and compress the bladder ; the air will pass through the fly, and set it in motion ; light the air at the end of the pipe, and a beautiful circle of fire will be formed by the motion of the bent tube, and the fired air which issues from its points. The pistol is fired as in experiment LXIX.

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 LXIX.

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 pure air, or the nitrous acid, to enable it to burn; but, if it is mixed with a certain quantity of common air, an explosion will take place in passing the electric spark through it.

Mr. Cavallo recommends a pistol made in the following manner, to those who wish to make experiments on the explosion of inflammable and dephlogisticated air, or with known quantities of common and inflammable 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 its ends, first with sealing wax, then with silk, and afterwards with sealing wax again. This wire is to be cemented in the perforation of the wooden piece, so as to

project about two inches within the tube, the rest is on the outside; that part of the wire which is within, is bent so as to be only about one tenth of an inch from the inside of the brass tube. *

To use this pistol; fill it with, and then invert it into a basin of water; make the required quantity of inflammable and common air in another vessel, by putting in known and proportionable measures of each; introduce this mixture into the pistol, and then stop it with a cork, take the pistol out of the water, and pass in the usual manner the spark of a charged jar through it, and the inflammable air will be fired.

The instruments for firing the inflammable air with the electric spark, are often made in the shape of a cannon.

* Cavallo on Air, p. 818.

C H A P. VI.

OF ELECTRIFIED POINTS.

EXPERIMENT LXX.

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 LXXI.

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 LXXII.

The lucid star is seen on the collecting points of a positive conductor, while a diverging cone will appear on a point placed at the end of the conductor.

To determine the direction of the electric fluid, has ever been an object of considerable

importance to the electrician; as it would enable him to decide on the truth of those theories, which have been invented to account for its phenomena, and greatly assist him in the progress of future discovery: To this end much stress has been laid on the different appearance of the light, which is perceived on the pointed ends of electrified conducting substances; as these have been supposed to elucidate fully this interesting question.

The electric fluid appears as a diverging stream darting forwards into the air, from a point electrified positively. The luminous appearance on a point negatively electrified, is that of a small little globule or star.

Now, as the air is known to resist the motion of the electric fluid, the rays of it would by this resistance be made to diverge; therefore, when this fluid is darting from a point into the air, it will assume the form of a lucid cone or brush, which is agreeable to experiments LXXI and LXXII.

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,

ther, the former account seems more conformable to nature, and the known laws of other fluids. The air resists the motion of the electric fluid equally. Therefore, when this fluid is coming from the air towards a pointed conductor, it would percolate slowly and invisibly through the air, but equally on all sides, till it comes so near as to be able to break through the intermediate space; but as this will be equal or nearly so all around, the negative electricity must appear like a steady luminous globule on the point *. Notwithstanding the apparent probability of the above reasoning, it may still be objected, that no decisive conclusion can be drawn from these appearances, as they may be varied by augmenting or diminishing the volume of the pointed body, and by a variety of other circumstances.

EXPERIMENT LXXIII.

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.

* Encyclopedia Britannica, 2699.

E X P E R I M E N T LXXIV.

Bring an excited glass tube near a point that is fixed at the end of a positively electrified conductor, and the luminous brush will be turned out of its direction by the action of the excited tube; if the tube is held directly opposite to the point, the brush will vanish.

E X P E R I M E N T LXXV.

Fix the point to the end of the negative conductor, the lucid star will turn towards the excited tube.

These two experiments coincide with and confirm experiments LXX, LXXI, LXXII, LXXIII, and lead to the same conclusion, viz. that the brush is a sign of positive, and the star an indication of negative, electricity, which is still further confirmed by the following experiment.

E X P E R I M E N T LXXVI.

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,

chine, 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 LXXVII.

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 its center with great rapidity. If the room be darkened, a circle of light will be formed by the electric fluid on the points of the wires. The re-action of the air on the diverging cone of electric matter gives the retrograde motion to the points of the wire.

The fly turns round in the same direction, whether it is electrified negatively or positively; though it will not move in vacuo, unless the finger, or some other conductor, is applied to the glass receiver opposite to one of the points, it will then begin to move, and continue to do so briskly till the glass is charged.

EXPERIMENT LXXVIII.

Electrify the two insulated wires MN, oP, 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 MN, oP.

EXPERIMENT LXXIX.

Fig. 36 represents a small crane, which will move from the same cause as the foregoing, and raise a small weight.

EXPERIMENT LXXX.

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 greafe, sealing wax, or sulphur.

EXPERIMENT LXXXI.

Immerse a metallic point in a metal vessel nearly filled with oil of vitriol, and placed on an electrified conductor, scarce any spark will pass to the point, although it is held very near the bottom of the vessel: If this is filled with essential oil of turpentine, a small light may be seen from time to time in the body of the fluid. If common oil is used, the point will take strong sparks, and the electric fluid in endeavouring to reach it, will occasion an ebullition in the oil.

So that the electric spark depends in a great measure on the conducting power of the medium through which it passes.

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 toward 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

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 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;

attracted; till the balls of the two phials approach pretty near together; they will then discharge their contents with a loud explosion, and the boats will afterwards sheer from each other.*

When the electric fluid percolates a wooden point, the stream or cone which issues from it, seems diluted, and something similar to the purple electric light, which is obtained in vacuo. The action of the electric fluid on the air, by an electrified point, produces a sensible aura, or wind, of sufficient force, as is seen above, to put light bodies in motion, or disturb the flame of a candle, and occasion an undulation in the fluids: the action of the fluid is so modified by points, as to produce an agreeable sensation, resembling a gentle breathing: this sensation may be rendered more or less stimulating, by the resistance the fluid meets with in its action on our bodies, an effect which is productive of great advantages in medical electricity.

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

C H A P. VII.

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.

The phænomena attending this very extraordinary experiment seemed totally inexplicable, till they were elucidated by the ingenious theory of Dr. Franklin; which, in a plain and clear manner, accounts for most of the difficulties which attend this intricate branch of electricity; and accomodates itself so easily and satisfactorily to a variety of appearances, as to make us almost lose sight of the objections against it.

E X P E R I M E N T LXXXII.

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

charged, or modify the electric fluid in a peculiar manner. To discharge the jar, or restore it to its 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.

E X P E R I M E N T LXXXIII.

Charge the Leyden bottle, then touch the outside coating 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

violate in our experiments; when this violation is small, the powers of nature operate in a gentle manner to restore 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

than on the quantity; hence a small phial fully charged will act nearly as strong as a larger jar which is half charged.

If a charged jar is coated very high, it will discharge itself before it has received near the charge it would take if the coating was lower. If it is coated very low, this part of the surface may be charged very high, but a considerable part of the glass is not charged at all.

When a jar is charged very high, it will often explode or discharge itself over the glass from one coated surface to the other; or, if the glass is thin, it will make a hole through it, and swell the coating on both sides, the glass in the hole will be pulverized, and very often a variety of fissures will proceed from it in various directions.

A Leyden jar very often recovers its electricity, in a small degree, after a discharge has been made; this second explosion is called the residuum of a charge.

The form or size of the glass is no ways material to the receiving of a charge.

To avoid receiving the electric shock, be careful never to touch the top and bottom of the jar at the same time, and never to enter a circuit formed between the inside and outside of a jar; for the effect of 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 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.

DR. FRANKLIN'S THEORY OF THE LEYDEN BOTTLE.

Glass is supposed to contain at all times, on its two surfaces, a large quantity of the electric fluid, which is so disposed, that if you increase the quantity on one side, the other must throw off an equal proportion; or, when one side is positive, the other must be negative. Now, as no more of the electric fluid can be forced on one side, than can go off on the other, there is no more in the 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 its place and situation; i. e. we may throw an additional quantity on one of its sides, if, at the same time, an equal quantity can escape from the other, and not otherwise. That this change is effected by lining parts of its two surfaces with a non-electric; through the mediation of which, we are enabled to convey the electric fire to every physical point of the surface we propose to charge, where it exerts its activity in repelling the electric particles naturally belonging to the other side; all of which have an opportunity of escaping by the lining in contact with this surface, which, for that

I 2

purpose,

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 its additional fire; and the outer, or negative side, equally desirous to attract what it has lost; but neither of them capable of having a change in its state effected, without the equal and cotemporary participation of the other. That notwithstanding the vicinity of these two surfaces, and the strong disposition of the electric fluid contained in one of them, to communicate its superabundance to the other, and of that to receive it, yet there is an impenetrable barrier between them; for so impermeable is glass to the electric fluid, (though it permits one side of it to act upon the other,) that its two surfaces remain in this state of contrariety, till a communication is formed between them, *ab extra*, by a proper conductor, when the equilibrium is suddenly and violently restored, and the electric fluid recovers its original state of equality on the two sides of the glass.

THE LEYDEN 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 by the other metallic coating, which is connected with the earth, and this contrariety will continue till the equilibrium is restored by connecting the opposite side with a conductor.

When an electric is excited, the two powers are said to be separated: they are also known to repel their own particles, and attract the contrary. When one side of a jar is made positive, may it not repel the positive electricity from the other side, separating it from the negative, which is strongly attracted through the glass?

The outside of the jar cannot then be said to be deprived of its electricity, but only has its fluid changed; and when the fluids are separated, they are ever eager to conjoin again.*

C O M B I N E D A P P A R A T U S .

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 such manner, as to render the apparatus extensively useful, without being complicated. A is an insulated pillar of glass, which is screwed to
the

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

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 shoulders a b, cd, then work the syringe, and in a few minutes

* We have now hit upon a plan of rendering these glasses so perfectly air tight, that the syringe is superfluous.

minutes the glasses will be sufficiently exhausted. H and I are two Leyden bottles, each 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 be screwed 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 LXXXIV.

Screw a Leyden phial, whose coating is free from points, upon an insulated stand, and place it so that its knob may be in contact with the conductor, taking care that no conducting substance is near the coating of the jar: turn the cylinder round a sufficient number of times to charge the phial, then examine it with a discharging

charging rod, and you will find it had received no charge; which shews clearly, that except the electric fluid can escape from one side of the jar, it can receive none on the other. If there are any points on the coating, or damp on the stand, the fluid will be carried off by them, and the jar will receive a small charge. The air which surrounds the coating, will also sometimes carry off a small quantity of electricity.

EXPERIMENT LXXXV.

Place the same insulated phial so that its knob may be about half an inch from the conductor, and while the cylinder is turning, hold a brass knob near the coating of the jar; this knob will receive a spark from the coating for every one that passes between the conductor and the knob, and the jar will in a little time be charged, by adding electricity to one side, and taking it away from the other.

EXPERIMENT LXXXVI.

Screw the phial a, fig. 42, on the insulated pillar d, and bring its knob in contact with the conductor; hold another bottle c, of the same size with a, so that its knob may be in contact with

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 its stand, and place it also on the table, but at some distance from the other; fit a brass ball to the bottom stem of the quadrant electrometer, and hold the electrometer by a 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.

E X P E R I M E N T LXXXVII.

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 its 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 LXXXVIII.

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 LXXXIX.

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 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 XC.

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

with its electrometer at the positive conductor, turn the cylinder, the electrometer will descend, and the bottle will be discharged by the contrary electricity.

EXPERIMENT XCI.

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 XCII.

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 its outer coating.

Charge the jar, and then remove the coatings, bring a pair of pith balls towards the jar, and they will be strongly attracted by it; replace the coatings, and the jar will give a considerable shock; which shews, that the power or force of the charge is resident in the glass, and not in the coatings.

EXPERIMENT XCIII.

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 XCIV.

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

string of shot to the bottom of the jar and let it communicate with the table, turn the machine, and a vivid spark will be seen between each of the shot, both within and without the bottle, as if the fire passed through the glass.

E X P E R I M E N T XCV.

Hold a phial in the hand which has no coating on the outside, and present its knob towards an electrified conductor; the fire, while it is charging, will pass from the outside to the hand, in a pleasing manner; on the discharge, beautiful ramifications will proceed from that knob of the discharger which is on the outside all over the jar.

E X P E R I M E N T XCVI.

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 XCVII.

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 its coating and you have a second discharge. Again, apply one ball of the discharger on the coating of B, and carry the other to the coating of A, and it will produce a third explosion. A fourth is obtained by applying the discharger from the coating of A to its knob.

The outer coating of the upper jar communicating with the inside of the under one, conveys the fluid from the conductor to the large jar, which is therefore charged positively; the upper jar does not charge, because
the

the inside cannot part with any of its electric fluid; but, when a communication is formed from the outside of A to the inside of B, part of the fire on the inside of A will be conveyed to the negative coating of B, and the jar will be discharged. The second explosion is occasioned by the discharge of the jar A; but, as the outside of this communicates by conducting substances with the positive inside of the jar B, if the ball of the discharging rod remains a small time after the discharge on the knob of A, part of the fire of the inside of A will escape, and be replaced by an equal quantity on the outside from the jar B, by which means A is charged a second time; the discharge of this produces the third, and of B the fourth explosion.

THE FOLLOWING PLEASING VARIATIONS OF THE FOREGOING EXPERIMENT WERE COMMUNICATED TO ME BY MR. J. FELL OF ULVERSTON:

A the upper 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 B to knob of A.

2d ditto. From coating of A to knob of A.

3d ditto. From coating of B to knob of A.

4th ditto. From coating of B to coating of A.

5th ditto. From coating of A to knob of A.

Coating of A applied to the conductor, and the charge given, touch the knob of A with one ball of the discharger, the other ball communicating with the earth, then proceed as follows.

1st discharge. Balls of discharger from coating of A to knob of A.

2d ditto. From coating of B to knob of A.

3d ditto. From coating of A to knob of A.

4th 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.

E X P E R I M E N T XCVIII.

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.

E X P E R I M E N T XCIX.

Electrify two pair of the pith balls which are fixed to the brass tubes, as in fig. 22, Pl. 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 balls will remain
in

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 C.

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 CI.

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 CII.

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 CIII.

At fig. 58 a wire is 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 CIV.

Place a clean, dry, and excited pane of glass, about one foot square, on an insulated box with
pith

pith balls, it will cause the balls to diverge with positive electricity, and they will continue to repel each other upwards of four hours in dry air. When the balls come together, remove the glass, and they will open with negative electricity; replace the glass, and they will close; remove it, and they will open again; and thus alternately as long as any electricity remains in the glass.

If the pane of glass be placed in a frame of wood, and a light pith or cork ball be laid on its surface, on presenting towards it the end of a finger, or the point of a pin, the ball will recede from them with a very brisk motion, and may thus be driven about on the surface of the glass, like a feather in the air by an excited tube. The ball being deprived of its electricity by the pin, it instantly flies to that part of the glass which attracts it most forcibly.

To excite the pane of glass; lay it upon a quire of large paper, well dried, and then rub it with a piece of clean dry flannel.

THE CONTRARY STATES OF THE DIFFERENT SIDES OF A LEYDEN PHIAL, AND THE DIRECTION OF THE ELECTRIC FLUID IN THE CHARGE AND DISCHARGE THEREOF, INVESTIGATED BY THE APPEARANCE OF THE ELECTRIC LIGHT.

In Chap. VI. we observed, that the different appearances of light on electrified points was deemed a criterion of the direction of the electric fluid; that the luminous star shews a point in receiving the electric matter, whilst the luminous brush, or cone, indicates that it is proceeding from a point.

We shall now examine the state of the different sides of the Leyden bottle by these appearances.

EXPERIMENT CV.

Screw the jar I on the insulating pillar, and the pointed wire into the hole g, place another pointed wire at the end of the conductor, bring the knob of the jar near this wire, and then turn the cylinder, a pencil of rays will diverge from
from

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 CVI.

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 CVII.

After the jar is charged, as in the foregoing experiments, turn that wire from the cylinder which before was nearest to it, then put the machine in action, and the afflux and efflux will be more apparent than before; one point throwing off, and the other receiving the fluid with extreme avidity, which will in a little time discharge the jar.

EXPERIMENT CVIII.

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 CIX.

Fig. 53 is an electric jar, BB 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

rod is moveable at pleasure in a spring tube N, that tube being fixed by a socket upon the top of the glass rod E, the charging wire communicates with the different divisions of the inside coating of the jar by horizontal wires.

Place the jar as usual, and put the machine in action, a small luminous spark will appear upon the upper point of the wire F, (a plain indication that the point is then receiving electricity from the upper ring of the coating on the outside of the jar) a fine stream or pencil of rays will at the same time fly off, beautifully diverging from the lower point of the wire F upon the bottom ring of the coating on the jar; when these appearances cease, which they will as soon as the jar is charged, let a pointed wire be presented towards the prime conductor, this will soon discharge the jar silently, during which, the lower point will be illuminated with a small spark, while the upper point of the wire will throw off a pencil of rays, diverging towards the upper ring of the coating.

EXPERIMENT CX.

Take a Leyden phial, the neck of which should not be very broad, set the coating on
the

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 CXI.

An insulated positively charged bottle will give a spark from its knob to an excited stick of wax, while no spark will pass between it and an excited glass tube.

EXPERIMENT CXII.

An analysis of the Leyden phial, by means of the Leyden vacuum E, fig. 49.—Screw this
this

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 CXIII.

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

This

This tube, when mounted on its insulating stand, may be used instead of the prime conductor, and all the common experiments may be performed with it; the tube will be luminous during the whole of the operation.

OF THE DIRECTION OF THE ELECTRIC MATTER IN THE DISCHARGE OF THE LEYDEN PHIAL.

EXPERIMENT CXIV.

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,

mosphere, since it would increase the intensity of the electric atmosphere.

E X P E R I M E N T C X V .

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.

E X P E R I M E N T C X V I .

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.

E X P E R I M E N T C X V I I .

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; now complete the
the

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 thro' the wire to the coating of the bottle. See fig. 64.

EXPERIMENT CXVIII.

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 immoveable, but D flew to the coating of the bottle.

EXPERIMENT CXIX.

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 ends 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

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 CXX.

Let the surfaces of an electric plate be very slightly charged and insulated, let an interrupted circuit be formed, the two powers will be visible, illuminating the points of the interrupted circuits, and each power will appear to extend farther 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 for this experiment was twelve feet.*

* Atwood's analysis of a course of lectures, p. 121.

EXPERIMENT CXXI.

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 CXXII.

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

EXPERIMENT CXXIII.

Let a coated phial be set on an insulating stand, and let its 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.*

*Fasten a pith ball electrometer by a little

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

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 CXXV.

Let the same phial, with the pith balls affixed to its 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 CXXVI.

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

tive 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 spark will strike the finger, and the bottle will be positively charged as before.

One of the positions which support the Franklinian hypothesis, has been already considered; we are now at a proper stage for pointing out some of 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, 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; now for every spark discharged from the prime conductor to the knob of the first jar, a spark will pass from the coating of the first to the knob of the second: now a common observer generally imagines that the fire runs through the glass; Dr. Franklin concludes it does not, because there is found a great accumulation of electricity on the inside of the jar, which manifests itself when the inside and outside are made to communicate with each other. But we cannot from this and similar experiments conclude that glass is impermeable, except we suppose the electric matter to be accumulated on one side of the glass, and deficient on the other; but this has never yet been proved, it has indeed been said, that if glass 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

* Encyclopedia Britannica, p. 2687.

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 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

* Ibid, p. 2687.

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.*

Dr. Franklin's theory rests upon the following position, "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 proof, and all the attempts that have hitherto been made to prove it, are only arguing in a circle, or proving the thing by itself. Thus, for instance, a body electrified positively, attracts one that is electrified negatively, because the first has too much and the other too little electric matter. But how do we know that one has too much and the other too little electricity? Because they attract each other,

Again, it has been proved, that when a jar is electrified positively, there is as constant a stream of fire from the outside coating, as

* Ibid, p. 2688.

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 in the above experiment one side has too much and the other too little electricity. Thus, in every instance, the arguments for Dr. Franklin's hypothesis return into themselves, and no conclusion can be drawn from them.*

If the reader wishes to investigate this subject further, he may consult Eccles's Philosophical Essays, Wilson's short View of Electricity, Marat's Recherches Physique sur l'Electricité, Milner's Observations, Lyons' Observations and Experiments on Electricity, and the Encyclopædia Britannica.

* Ibid, p. 269r.

C H A P. VIII.

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 inconveniencies 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

* 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.

substances.

substances. By this means the resisting medium, through which the spark is to pass, may be so prepared as to augment its power. If the spark is made to pass through a hole in a plate of glass, 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. I hope he will be induced to communicate this, as well as the rest of his important discoveries, to the public.

EXPERIMENT CXXVII.

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 CXXVIII.

Discharge a battery through a quire of paper, a perforation will be made through it; each of the leaves is protruded by the stroke from the middle towards the outward leaves, as if the fire darted both ways from the center. If the paper is very dry, the fire meets with more difficulty in its passage, and the hole is small. If that part of the paper, through which the explosion is made, is wet, the hole is larger, the light more vivid, and the explosion louder.

EXPERIMENT CXXIX.

The discharge of a battery through a small steel needle will, if the charge is sufficient, communicate magnetism to the needle.

EXPERIMENT CXXX.

The discharge of a battery through a small and slender magnetic needle, will generally destroy the polarity of the needle, and sometimes invert

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 CXXXI.

Let a quire of paper be suspended by a line in the manner of a pendulum from any convenient altitude, so that its plane may be vertical. Let the largest charge from a battery be caused to pass through it, while quiescent in an horizontal direction perpendicular to the plane, the rods of communication not touching the paper; the phenomena are: first, the aperture mentioned in Exp. cxxviii, 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

Acquire of the thickest and strongest paper was made use of for this experiment, the height from which it was suspended sixteen feet. It is an extraordinary appearance on the hypothesis of a single electric fluid, that a force sufficient to penetrate a solid substance of great tenacity and cohesive force, should not communicate the smallest motion to the paper, when a breath of air would cause some sensible vibration in it. But this difficulty is not unanswerable; for a velocity may be assigned, with which a body impinges against and passes through a pendulum of any given weight and resisting force, so that a smaller angular velocity shall be communicated to it, than any that shall be proposed, and we know no limit to the velocity of the electric power or powers. But the other phenomenon, i. e. the opposite direction in which the leaves are protruded, tends very much to strengthen the opinion of two opposite currents: perhaps either of those phenomena considered simply, may admit of an easy solution from the hypothesis of a single power, when they are taken both together, it seems more difficult to reconcile this hypothesis with matter of fact *.

* Atwood's Analysis,

EXPERIMENT CXXXII.

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
the

the electric fluid, and therefore in estimating the conducting powers of different substances, their length must be particularly attended to.

EXPERIMENT CXXXIII.

Inclose a very slender wire in a glass tube, discharge a battery through this wire, and it will be thrown into globules of different sizes, which may be collected from the inner surface of the tube: they are often found to be hollow, and little more than the scoria of the metal.

Many experiments have been made, in order to try the different conducting powers of metals, by passing the discharge of a battery through them; but it has not yet been determined, whether the greater facility with which some metals are exploded depends on the ease with which the fluid passes through them, or whether it proceeds from the degree of resistance they make to its passage, or from a want of ductility in the metal, which is therefore less capable of expansion.

EXPERIMENT CXXXIII.

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 CXXXIV.

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, EF, fig. 33, to touch the ends of the leaves, and pass a discharge through them, which will force part of the metal into the glass, and stain it with a colour which differs from the metal that is made use of. The metallic leaf should be made narrowest in the middle, because the force of the electric fire is in proportion to its density, which is increased when the same quantity of fire is compelled to pass through fewer conducting particles.

The

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 CXXXVI.

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 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

formed by Mr. Morgan, that if the glass is cemented down the effect is the same as when it is pressed by the weights; and this mode is in various experiments more convenient.

Place a piece of very dry white wood between the balls of the universal discharger, the fibres of the wood to be in the same direction with the wires, pass the shock through them, and the wood will be tore to pieces, or run the points into the wood, and then pass the shock through them.

EXPERIMENT CXXXVII.

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 CXXXVIII.

Fig. 66, a, represents an insulated rod, nearly touching a charged jar, b is another insulated rod, placed in a line with and near to the former; make the discharge by the rod e, from
M which

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 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

greater the fusion, the greater is the dispersion of light bodies near it.

EXPERIMENT CXXXIX.

If circuits, different in length and of different substances, form a communication between two charged surfaces of an electric plate, it is observed, the discharge will be made through the best conductors, whatever be the length of the others.

2. If circuits of the same substance be different in length, the discharge will be made through the shortest of them.

3. If the circuits be the same in every respect, the discharge will be made through many of them at the same time.*

If one circuit consists of undried wood, and is of considerable length in comparison of another which consists of metal, the discharge will be made wholly through the latter, unless the charge should be very great, in which case some small part will pass through the wood.

If a short metallic rod and any part of the human body form two circuits between the same charged surfaces, the discharge will, in general, be made wholly through the metallic rod; but

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

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 CXL.

Mr. Henly 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 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

teen square feet of coated surface, through three different chains at the same time, fig. 67, 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, and 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 fir-wood. On making the discharge upon the plate, both the chains were luminous through their whole lengths, as was also the saw-dust, which was covered by a streak of light, making a very pleasing appearance.

At the glass-house there is generally a great number of solid sticks of glass, about one quar-

ter 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 zooth 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 CXXI.

Pass the shock through this small thread of quicksilver, which will be instantly dislodged, and will break or split the tube in a curious manner. †

EXPERIMENT CXXII.

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 dis-

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

charge, the water will be dispersed in every direction, and the tube blown to pieces by the discharge.

The electric fluid, like common fire, converts the water into an highly elastic vapour. Dr. Franklin, on repeating this experiment with ink, could not find the least stain upon the white paper, on which the tube had been placed. Beccaria passed the shock through a drop of water, which was supported, in the center of a solid glass ball, between the ends of two iron wires, and the ball was shivered in pieces by the explosion. On this principle he contrived what he calls an electrical mortar, which will throw a small leaden ball to the distance of twenty feet. It is clear, from several of the foregoing experiments, that the electric fluid endeavours to explode in every direction the parts of the resisting substances through which it passes.

EXPERIMENT CXLIII.

Place a building, which is formed of several loose pieces of wood, on a wet board in the middle of a large basin of water, let the electric flash from a battery be made to pass over the board, or over the water, or over both;

the water will be strongly agitated, and the building thrown down. The report is louder than when the explosion passes only through the air. The electric fluid endeavours to pass near the surface of the water where it meets with more resistance, than if it is forced to pass through it. This partly arises from the power the electric fluid has of raising an expansive vapour from the surface of the water, which drives off the resisting air.

A discharge passed over the surface of a piece of ice will leave on it small unequal cavities, exhibiting the same appearance as if a hot chain had been placed on it.

A discharge sent through a green leaf tears the surface in various directions, leaving an image in miniature of some of the effects of lightening. A discharge will pass to a certain distance over spirit of wine, without inflaming it; but, if the distance is increased, it will set it on fire. From hence it appears, that the facility with which the electric fire is transmitted over the surface of moist substances, depends on the ease with which they are turned into vapours.

The discharge, in melting the particles of metals, drives into its passage the conducting vapours which arise from them; and, in proportion.

portion as the parts of any body are more readily driven into vapour or dust, the spark will run to a greater distance.

EXPERIMENT CXLIV.

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 CXLV.

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 immersed 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 CXLVI.

Place a plain piece of metal between the
points

points of the univerfal 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

middle of a circuit of two miles, and felt himself shocked at the same instant he saw the phial discharged.

Notwithstanding this surprizing 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 with this immeasurable velocity; and it is also certain, that this fluid is resisted in its passage through, or over, every substance.

The wonderful part of the foregoing experiments will vanish, if we admit the reasoning of Mr. Volta on this subject; and the reader will find his reasoning considerably strengthened by experiments cxx, cxxi, cxxii of this essay, which were originally made by Mr. Atwood; 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.

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

Let

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 extream rapidity with which the fire passes, did not prevent our perceiving the successive commotions received by the persons who form the chain, we should find they did not follow the order *o, n, m, l*, but were felt simultaneously, first at the two extremities *o* and *a*, then at *n* and *b*, *m* and *c*, &c. advancing towards the middle of the chain. Agreeable to this, if the bottle is small, the longer the circuit is made, those who are furthest from the extremities find the shock weaker.

To

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 *e*, and then through him to the outside, without acting on *f, g, h*, which would be out of its circuit. But, contrary to this, the fluid goes out of the direct course, to follow that of the conducting persons, which afford it a proper receptacle, and comes to the outside by another source. The fire which goes from the inside from *e* to *f, g, h*, gives them a sensible sensation in their hands and their heels, shewing itself by a spark, if the hands and the feet are separated a little from each other, and finishes by dissipating itself in the common reservoir. In the same manner *d*, who first 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,

source,

source, a sufficient quantity is taken to supply the deficiency of the exterior surface.

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

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

C H A P. IX.

ON THE INFLUENCE OF POINTED CONDUCTORS
FOR BUILDINGS.

THE importance of electricity, as well as its universal agency, becomes more conspicuous, in proportion as our acquaintance with it increases. We find no substance in nature which is not acted on by it, either as a conductor or non-conductor; and discover, that the surprising phenomena of thunder and lightning, owe their origin to, and are of the same nature with it. Very little progress had been made in electricity, when the analogy between the electric spark and lightning was discovered: but the sublime idea of realizing these conjectures, and proving that the fire which flashes in the sky, is the same agent which explodes and gives a shock in our experiments, was given to Dr. Franklin; who also first suggested the utility of pointed conductors of metal, to preserve buildings from the dreadful effects of lightning; an idea which was received with general applause and approbation. Since this period, many electricians have been induced to change their opinion relative to the utility of these conductors;

tors; 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 is pointed, than to one which is flat or globular;

globular; because, in this case, the elasticity of the electric fluid, and its power to break through the air, are weakened by the flat surface which acquires a contrary electricity, and compensates the diminished intensity more than a point can; the point being easily rendered negative, while the effort of the fluid to escape from the electrified body, is greater than when it is opposed by a flat surface. So that it is not the particular property of a point, or flat, but the different state of the electrified body, which causes it to part with its electricity easier, and from a greater distance, when a pointed conducting substance is presented to it, than it does to a flat or globular conductor.*

The capacity of conductors to hold electricity, is in proportion to the surfaces which are free, or uninfluenced by a similar atmosphere; a circumstance which will, more or less, affect those conductors which are applied to buildings, according to the state of the clouds and their atmosphere, the time their influence has been exerted, the nature of the conducting strata of the earth, and its electric situation.

Besides, the electric powers must be separated before any body can be electrified; and the point must be in a state to give one kind of electricity, before it can receive the other.

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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 its lower corner ; the brass ball on the wire may be taken off, in order that the pointed end may be occasionally exposed to receive the explosion.

EXPERIMENT CXLVII.

Place a jar with its knob, in contact with the conductor, connect the bottom of the jar with the hook H, then charge the jar, and bring the ball under the conductor, and the jar will be discharged by an explosion from the conductor to the ball of the house. The wires and chain being all in connexion, the fire will be conveyed to the outside of the jar, without affecting the house : but if the square piece of wood is placed so that the wires are not connected, but the communication

tion 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 its contents on a weather cock, or any other metal, at the top of a building. From this experiment many have inferred, that if there is a 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.

E X P E R I M E N T CXLVIII.

Mr. Henly 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.

EXPERIMENT CXLIX.

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 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.

EXPERIMENT CL.

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.

EXPERIMENT CLI.

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, (see fig. 70,) 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 A, which was three quarters of an inch in diameter, the jar was discharged by a loud and full explosion, and the chain was very luminous.

EXPERIMENT CLII.

Mr. Henly suspended by a silk string, from one end of a wooden bar, which turned freely in a horizontal direction upon the point of a needle, a large bullocks bladder, gilded with leaf copper; the bladder was balanced by a weight at the other end of the arm; (see fig. 71;) he gave a strong spark from the knob of a charged 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 its electricity in a full spark. He then gave it another spark, and presented a pointed wire towards the bladder, which never approached to the point, nor ever gave any spark, the electricity being carried off.

EXPERIMENT CLIII.

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 altogether towards the prime conductor, where they will continue as long as the point remains under them.

EXPERIMENT CLIV.

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 electricity, does not extend round the electrified body, when means are used to keep up the supply of electricity.

Fig. 72 represents an oval board, three feet long and two feet broad, coated on both sides with tin-foil, and suspended by silk lines from a double hook; this turns on an axis, which is fastened to one arm of a nice balance, and counter-poised 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.

E X P E R I M E N T C L V .

Connect the pendulous board with the prime conductor by a small wire, a few turns of the machine will electrify the apparatus. When this experiment was made, the board was attracted by the table at fifteen inches distance, and discharged itself with a strong spark. The same happened to a metal ball which was placed on the table, the board approaching till it was about one inch from the ball, and then discharging itself by a spark. If a point is fixed on the board instead of a knob, the pendulous board, though it begins to approach, stops at about four or five inches from the table, and it will not approach nearer, or give a spark: a small light is seen upon the point in the dark. A Leyden phial was then connected with the prime conductor;

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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.

The following experiment is extracted from "An Account of Experiments made at the Pantheon, on the Nature and Use of Conductors," by Mr. Wilson. It was made in order to point out what he deemed erroneous in an experiment of Mr. Henly, which is the 151st of this Essay,

The circuit of communication was divided into two parts:

A bent rod of brass, with a ball of the same metal, three quarters of an inch in diameter, screwed on to the upper extremity of it, and a copper ball, five inches in diameter, screwed on to the lower end, forms one of the parts. This part was supported by a stand of wood that had a cap of brass at the top, into which the brass rod was occasionally screwed.

The other part of the circuit consisted of a brass rod also ; one end of which branched out in the form of a fork, with two prongs that pointed towards the center of the copper ball ; and those prongs were so constructed, that either of them could be made longer or shorter, just as the experiment required. On the end of one of the prongs was fixed a ball of brass, three quarters of an inch in diameter, and on the other a sharp steel point or needle. The shoulder of this fork screwed into a small plate of iron, that was fixed on the inside of a wooden vessel, which contained the greatest part of a cylindrical glass jar, twelve inches three quarters high, and about four inches in diameter. This glass was rather thick than otherwise, and the coating of it (which was tin-foil) measured nearly 144 square inches on each surface. Besides this coating, part of the inside of the wooden vessel was coated also with tin-foil, for the purpose of making a secure communication between the iron plate and the outward coating of the jar. Within the jar itself, was fitted a cylinder of wood, that was covered with tin-foil also, to make a communication between the inside coating of the glass and a brass rod, that was fixed upright in the center of the wooden cylinder. This upright rod having a ball of brass at the
end,

end, three quarters of an inch in diameter, was bent towards the first part of the circuit; so that the two balls A and B, in fig. 73, being upon a level, looked towards each other, but were placed from time to time at different distances, as occasion required; and thus answered the purpose of an electrometer.

Mr. Wilson began the experiments where the electrometer was struck at the greatest distance, and then adjusted the distances of the ball accordingly; so that if the point was struck when they were adjusted, the moving of the ball the thirty-second part of an inch would occasion the ball to be struck in preference to the point, and *vice versa*. Afterwards he lessened the striking distance of the electrometer, in every experiment, till he attained the least distance.

Upon reversing part of the apparatus, and fixing the ball to the bottle, and the fork to the stand, all those experiments were repeated again; the copper ball being put nearest to the glass, in the place of the forked part, and the forked part in the place of the copper ball. This set of experiments being compleated, he made others, where the ball only was opposed; and after them, where the point only was opposed to the copper ball.

Having

Having gone through all these experiments, as they are set down in the first table, he then repeated the experiment with the chain, after Mr. Henly's manner. The result of which, and with the apparatus reversed, will appear in the second table.

TABLE

TABLE I.

EXPERIMENTS MADE AT DR. HIGGINS'S, JUNE 19,
1778, WITH THE LEYDEN PHIAL AND FORKED
APPARATUS.

N-B. The measures expressed in the following tables were taken from a scale containing 32 parts in one inch.

The number opposite the word electrometer, denotes the distance between the balls which constitute the electrometer; and the numbers opposite to the words *ball* and *point*, shew the greatest distance at which they were respectively struck.

	<i>Ball and Point opposite the Leyden Phial.</i>	<i>Ball Pt. only. only.</i>	<i>Apparatus reversed.</i>	<i>Ball Pt. only. only.</i>
I.	{ Electrometer Ball — — Point — —	32 { 32 { 32 34 { 48 { — 45 { — { 88	{ 32 34 43	{ 32 { 32 36 { — — { 42
II.	{ E. — — B. — — P. — —	28 { 28 { 28 30 { 43 { — 38 { — { 78	{ 28 36 42	{ 28 { 28 33 { — — { 39
III.	{ E. — — B. — — P. — —	25 { 26 { 26 28 { 36 { — 37 { — { 67	{ 25 31 32	{ 26 { 26 32 { — — { 33
IV.	{ E. — — B. — — P. — —	20 { 20 { 20 28 { 29 { — 51 { — { 64	{ 20 29 28	{ 20 { 20 25 { — — { 24
V.	{ E. — — B. — — P. — —	16 { 16 { 16 22 { 20 { — 44 { — { 47	{ 16 22 24	{ 16 { 16 23 { — — { 26
VI.	{ E. — — B. — — P. — —	13 { 13 { 13 21 { 14 { — 38 { — { 36	{ 13 16 22	{ 13 { 13 18 { — — { 22
VII.	{ E. — — B. — — P. — —	10 { 10 { 10 12 { 10 { — 18 { — { 25	{ 10 13 20	{ 10 { 10 12 { — — { 20

TABLE

T A B L E II.

EXPERIMENTS WITH THE CHAIN, AFTER MR. HENLY'S MANNER.

<i>Point and Ball opposite the Leyden Pbial.</i>				<i>Apparatus reversed.</i>					
{	Electrometer	—	21	—	{	23	repeated at different times.	{	23
	Ball	—	26	—		28			26
	Point	—	24	—		26			30

T A B L E III.

THE EXPERIMENTS OF THE 2d AND 3d TABLE, REPEATED AT MR. PARTINGTON'S, JUNE 23, 1778, A BRASS CHAIN BEING MADE USE OF INSTEAD OF THE FORKED APPARATUS.

	<i>Ball and Point opposite the Leyden Pbial.</i>	<i>B. P. only.</i>	<i>B. P. only.</i>	<i>Apparatus reversed.</i>	<i>B. P. only.</i>	<i>B. P. only.</i>					
I.	Electrometer	32	{ 32	{ 32	{	32	{	32			
	Ball	—	40	{ 39		{ 30		29	{	—	
	Point	—	76	—		{ 38		—	{	39	
II.	E.	—	28	{ 28	{ 28	{	28	{	28		
	B.	—	33	{ 36	{ 29		28		{	—	
	P.	—	72	—	{ 37		—		{	38	
III.	E.	—	25	{ 26	{	repeated {	25	{	26		
	B.	—	33	{ 33			28		27	{	—
	P.	—	46	—			{ 35		37	{	37
IV.	E.	—	20	{ 20	{ 20	{	20	{	20		
	B.	—	21	{ 23	{ 24		24		{	—	
	P.	—	50	—	{ 26		—		{	27	
V.	E.	—	16	{ 16	{	alternately.	16	{	16		
	B.	—	21	{ 15			{ 19		19	{	—
	P.	—	55	—			{ 21		—	{	24
VI.	E.	—	13	{ 13	{ 13	{	13	{	13		
	B.	—	16	{ 11	{ 14		15		{	—	
	P.	—	44	—	{ 19		—		{	22	
VII.	E.	—	10	{ 10	{	alternately.	10	{	10		
	B.	—	11	{ 9			{ 11		12	{	—
	P.	—	38	—			{ 19		—	{	19
	{	Electrometer	—	21	} Apparatus reversed.	{	23	{	23		
	Ball	—	24	25			25				
	Point	—	64	30			30				

EXPERIMENT CLVI.

If an interruption is made in each of two similar circuits, which form communications between the charged surfaces of an electric plate, and if the space of air in one of the interruptions is terminated by points, and in the other by balls, the discharge will be made through the circuit of which the points make a part, although the length of the interrupted space of air is considerably greater than that in the other circuit.

Before any discharge takes place, the two powers are suspended on the opposite surfaces of the charged electric.

An electric plate may be discharged two ways, either silently in some sensible portion of time, or by explosion in an instant: in either case experiments abundantly shew that *cæteris paribus*, the discharge will be made through a pointed body in preference to a round termination.

When a pointed body is presented to any charged surface, a cylindrical plate of air, of evanescent diameter, is charged with the contrary electricities strongly attracting each other through it; and the quantity of air being so small,

small, there will be little resistance to their union; the discharge will be made by explosion in preference to the gradual discharge, according as the opposite surfaces (the pointed body and the surface opposed to it) are larger, as they are nearer each other, and as the charge is greater; for it will be observed that a point, or very small spherical termination, which is in a physical sense a point, will discharge any quantity of electricity silently and gradually without explosion, while it is at a sufficient distance from the opposite charged surface: by bringing it nearer, the method of discharge will be altered; which will now be a succession of small explosions very quickly following each other. The reason of this seems to be, that when the charged surfaces are very near, there is not sufficient time for the contrary powers to unite gradually, nor sufficient room in which they may be diffused among the surrounding air.

This is confirmed by again removing the two opposed surfaces to such a distance that the discharge may be made gradually; in this case if the parts of the apparatus are so disposed by any kind of contrivance, that the discharge must necessarily be made suddenly, the method of discharge will be again altered, becoming

now

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 from the effects of lightning, will contribute to discharge the electricity from a cloud that passes over them: and a greater quantity of the discharge will pass through a pointed conductor, than through one which is terminated by a ball; but whether the discharge will be made by a gradual current, or by explosion, will depend on the suddenness of the discharge, on the proximity of the cloud, its motion, and the quantity of the electricity contained in it. If a small cloud hangs suspended under a large cloud loaded with electric matter, pointed conductors on a building underneath will receive the discharge by explosion in preference to those 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 hollow cone, formed into an electrified solid, the surfaces of the two cones being equi-distant, 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.

EXPERIMENT CLVII.

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

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 its surface, there will follow an explosion in the earth as well as in the atmosphere, which will produce concussions and other phœnomena 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.

OBSERVATIONS ON THE ACTION OF CONDUCTORS.

“ Ever since the discovery of the identity of electricity and lightning, it has been allowed by all parties, that conductors of some kind are in a manner necessary for the safety of buildings in those countries where thunder storms are very frequent. The principle on which

they act is this : that the electric fluid, when impelled by any power, always goes to that place where it meets with the least resistance. Now, as metals are found to give the least resistance to its passage, it will always choose to run along a metalline rod, in preference to a passage of any other kind. But it is necessary to observe here, that electricity never strikes a body merely for the sake of the body itself, but as by means of that body it can arrive at the place of its destination. When a quantity of electricity is collected from the earth, by means of an electric machine, a body communicating with the earth will receive a strong spark from the prime conductor ; it receives this spark not because it is capable of containing all the electricity of the cylinder and conductor, but because the natural situation of the fluid being disturbed by the motion of the machine, a stream of it is sent off from the earth. The natural powers, therefore, make an effort to supply what is thus drained off from the earth ; and, as the individual quantity which comes out is most proper for supplying the deficiency, as not being employed for any natural purpose, there is always an effort made for returning it to the earth. No sooner, then, is a conducting body, communicating with the earth,

earth, presented to the prime conductor, than the whole effort of the electricity is directed against that body; not merely because it is a conductor, but because it leads to the place where the fluid is directed by the natural powers by which it is governed, and at which it would find other means to arrive, though that body were not to be presented. That this is the case we may easily see, by presenting the same conducting substance in an insulated state to the prime conductor of the machine, when we shall find only a small spark will be produced. In like manner, when lightning strikes a tree, a house, or a thunder-rod, it is not because these objects are high, or in the neighbourhood of the cloud, but because they communicate with some place below the surface of the ground, against which the impetus of the lightning is directed, and at that place the lightning would certainly arrive, though none of the above-mentioned objects had been interposed.

“When the atmosphere begins to be electrified, either negatively or positively, the earth, by means of the inequality and moisture of its surface, but especially by the vegetables which grow upon it, absorbs that electricity, and quickly becomes electrified in the same man-

ner with the atmosphere; this absorption, however, ceases in a very short time, because it cannot be continued without setting in motion the whole of the electric matter contained in the earth itself. Alternate zones of positive and negative electricity will then begin to take place below the surface of the earth, for reasons given in the course of this essay. Between the atmosphere and one of these zones the stroke of lightning will always be. Thus, supposing the atmosphere is positively electrified, the surface of the earth will, by means of trees, &c. quickly become positively electrified also, we will suppose to the depth of ten feet: the electricity cannot penetrate further, on account of the resistance of the electric matter in the bowels of the earth. At the depth of ten feet from the surface, a zone of negatively electrified earth begins, and to this zone the electricity of the atmosphere is attracted; but to this it cannot get, without breaking through the positively electrified zone, which lies uppermost, and shattering to pieces every bad conductor which lies in its way. We are therefore sure, that in whatever place the outer zone of positively electrified earth is thinnest, there the lightning will strike, whether a conductor happens to be present or not. - If there is a
con-

conductor, either with a knob or sharp pointed, the lightning will infallibly strike it: but it would also have struck a house situated on that spot without any conductor; and if the house had not been there, it would have struck the surface of the ground itself. Again, if we suppose the house with its conductor to stand on a part of the earth where the positively electrified zone is very thick, the conductor will neither silently draw off the electricity, nor will the lightning strike it; though, perhaps, it may strike a much lower object, or even the surface of the ground itself at no great distance; the reason for which undoubtedly is, that there the positive electrified zone is thinner than where the conductor was.

“ To suppose that a pointed conductor will exhaust a thunder cloud of its electricity, must at first sight appear trifling, to insist on it, ridiculous. Innumerable objects are all conspiring to draw off the electricity as well as the conductor, if it could be drawn off; but of effecting this, there is an impossibility, because they have the same kind of electricity with the clouds themselves.

“ Besides, Beccaria has observed, that during the progress and increase of the storm, though the lightning frequently struck to the earth,

yet the same cloud was the next moment ready to make a greater discharge, and his apparatus continued to be as much affected as ever.

“ The conductor has not even the power of *attracting* the lightning a few feet out of the direction it would choose itself: of this we have a most decisive instance in what happened to the magazine at Purfleet, in Essex. That house was furnished with a conductor, raised above the highest part of the building; nevertheless, a flash of lightning struck an iron cramp in the corner of the wall of the building, considerably lower than the top of the conductor, and only forty-six feet in a sloping line distant from the point.

“ The conductor, with all its power of *drawing off* the electric matter, was neither able to prevent the flash, nor to turn it forty-six feet out of its way. The matter of fact is, the lightning was determined to enter the earth at the place where the Board-house stands, or near it; the conductor, fixed on the house, offered the easiest communication, but forty-six feet of air intervening between the point of the conductor and the place of the explosion, the resistance was less through the blunt cramp of iron, and a few bricks moistened with the rain to the side of the metalline conductor, than
through

through the forty-six feet of air to its point, for the former was the way in which the lightning actually passed.

“ The zig-zag kind of lightening 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 which 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 lightening is that which assumes the form of balls. These are produced by an exceeding great power of electricity, gradually accumulated till the resistance of the atmosphere is no longer able to confine it. In general, the lightening 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 def-

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 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

i. e. it would have been at a loss for a conductor. The negative side of the battery was the place of its destination, but to that it could not easily have got, because of the great quantity of atmosphere which lay in its way, and the incapacity of the neighbouring bodies to receive it. But, while the electric matter was thus stationary for want of a conductor, if any one standing near, or touching the negative side of the battery, presented a finger to this seemingly inoffensive luminous body, he would be instantly struck very violently, because a free communication being now made by means of his body, the powers by which the electric fluid is impelled from one place to another would urge it upon him. But if we suppose a person, who has no communication with the battery, to present his finger to the same body, he may perhaps receive a slight spark from it, but not a shock of any consequence.

“ We may now account for the seemingly capricious nature of all kinds of lightning, but especially of that kind which appears in the form of balls. Sometimes it will strike trees, high houses, &c. without touching cottages, men, or other animals, who are in the neighbourhood; in other instances, low houses and cattle have been struck, while high trees
and

and steeples in the neighbourhood have escaped *. The reason of this is, that in thunderstorms 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 earth's surface; the electric matter flows out from it first into the atmosphere all round, and while it is doing so, the atmosphere is electrified negatively. In proportion, however, as the current pervades greater and greater portions of the atmospheric space, the resistance to its motion increases, till at last, the air becomes positively electrified as well as the cloud, and they both act as one body. The surface of the earth then begins to be electrified, and it silently receives the electric matter by means of the trees, grass,

* 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.

&c. which grow upon its surface, till at last, it becomes also positively electrified, and begins to send off a current of electricity from the surface downwards.

“ The causes which first produced the electricity still continuing to act, the power of the electric current becomes inconceivably great. The danger of the thunder-storm now begins; for, as the force of the lightening is directed to some place below the surface of the earth, it will certainly dart towards that place, and shatter every thing to pieces which resists its passage.

“ The benefit of conducting rods will now also be evident. For we are sure, the electric matter will, in all cases, prefer that way where it meets with the least resistance, and this is over the surface of metals. In such a case, therefore, if there happen to be a house furnished with a conductor directly below the cloud, and at the same time a zone of negatively electrified earth not very far below the foundation of the house, the conductor will almost certainly be struck, but the building will be safe. If the house wants a conductor, the lightening 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

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-forms, 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.

C H A P. X.

TO CHARGE A PLATE OF AIR.

AS air is an electric, it will receive a charge like all other electric substances. To this property may be ascribed many of the phenomena which are observed in the course of the common electrical experiments; for the air which surrounds an electrified non-electric is always in some degree charged with the fluid, and thus acts upon the atmosphere of the electrified conductor, not only by its pressure, but also by its acquired electric powers; and that it pervades the air to a considerable distance is evident, from the different methods by which the air of a room may be electrified.

Cover two large boards with tin-foil; suspend one by 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 convenient. These boards may be considered

as the coatings to the plate of air which is between them.

E X P E R I M E N T C L V I I I .

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 its tension, or the force with which it endeavours to fly off from the electrified body.

The two plates, when in contrary states, strongly attract each other, and will come together, if they are not kept asunder by force. A spark will sometimes pass between the plates,
and

and destroy the electricity of each. If an eminence is placed on the under plate, the spark, in the spontaneous discharge, will strike it. The experiments with these boards will be more pleasing, if one surface of the upper board is covered with gilt leather. The two plates, when charged, are supposed to represent the state of the earth and the clouds in a thunder-storm. The clouds being in one state, and the earth in an opposite one, while the plate of air acts as the electric, and the spontaneous discharges exhibit the phenomena of lightning.

An observation has been made on this experiment, which seems to affect one of the principal supports of the received theory. I have subjoined it, in order to invite those who are conversant with electricity to a closer investigation of the subject.

In this experiment it seems impossible to deny, that the air is penetrated by the electric fluid. The distance between the plates is so small, that it must appear absurd to say that this space is penetrated only by a repulsive power, when in other cases we see the fluid pervading much greater spaces of air. But if one electric substance is penetrable by the electric fluid, we must be led strongly to suspect

at least that all the rest are so too. If glass was altogether impenetrable to the fluid, it is natural to think that it would run over its surface very easily. But instead of this, so great is its propensity to enter, that a shock sent through between two glass plates, if they are pressed pretty close together, always breaks them to pieces, and even reduces part of them to a powder like sand. This last effect cannot be attributed to any other than the electric fluid entering the pores of the glass, and meeting with resistance, the impetus of its progressive motion violently forces the vitreous particles asunder in all directions.

E X P E R I M E N T C L I X .

Turn that side of the upper board on which the gilt leather is pasted towards the lower one; place one or two small metal hemispheres on the lower board; connect the upper board with the positive conductor, and the lower one with that which is negative, put the machine in action, and the upper board will discharge the whole of its contents on one of the hemispheres in a strong flash, attended with a smart explosion; vivid 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 lightening, 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, and the flashes of light will extend further, and the explosion will be louder.

E X P E R I M E N T C L X .

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 show any signs of attraction.

E X P E R I M E N T C L X I .

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 CLXII.

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.

C H A P. XI.

OF THE ELECTROPHORUS

FIG. 73 represents an electrophorus. This instrument was invented by Mr. Volta, of Coma in Italy.* It consists of two plates of a circular form, the under plate is of brass covered over with a stratum of an electrical substance, generally of some negative electric, as wax, sulphur, &c. the upper plate is of brass, with a glass handle screwed on the center of its upper surface.

Resinous electrics generally succeed better for an electrophorus than those made only of glass, not only as they are less affected by the humidity of the air, but as they seem to have the power of retaining longer the electricity which is communicated to them.

To use this apparatus, first excite the under plate c, by rubbing its coated side with a piece of clean dry flannel, or hare-skin; when this plate is well excited, it is to be laid on the table with the electric uppermost. Secondly,

P 3

place

* Mr. Wilck, in August, 1762, contrived a resinous apparatus, to which he gave the name of a perpetual electrophorus. See Scripta Academiæ Suec. 1762.

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.

The following experiments, which were made with a view to analyse this curious little instrument, are extracted from a paper of Mr. Achard's, in the *Memoirs de l'Academie Royale de Berlin* for 1776.

EXPERIMENT CLXIII.

Mr. Achard placed horizontally a circular plate of glass, which was about two tenths of an inch in thickness, and one foot in diameter, on a tin plate, which only touched the glass in a few places; having excited the upper surface of the glass, it produced all the effects of the electro-

electrophorus; from whence he infers, that it is not necessary that the inferior metallic plate should touch exactly in all its surface the electric coating.

EXPERIMENT CLXIV.

He insulated, in a horizontal position, a plate of glass of one foot diameter, he excited this, and then applied the upper plate in the usual manner, and obtained a successive number of weak sparks; but in order to procure them, he was obliged to let the finger remain sometime on the upper plate. If, instead of insulating the plate of glass by glass, he insulated it by wax or pitch, he constantly found that the sparks were stronger. From this experiment he concludes, that the inferior plate is not necessary to the production of the effects observed in this instrument, and that when deprived of it, it retains all its properties.

EXPERIMENT CLXV.

Having excited the upper surface of an electrophorus of wax, he placed the upper plate on it, and after some time lifted it off by its insulating handle, without previously touching

it with the finger; it gave no spark, and was not possessed of the least power of attraction and repulsion; which proves, that the electrophorus cannot render the upper plate electric, unless it is touched by a body which is capable of giving or taking electricity from it,

EXPERIMENT CLXVI

Place the upper plate on an excited electrophorus, bring a finger near the upper plate, and a spark will pass between them. Now as the electric fluid never appears as a spark, except when it passes with rapidity from one body to another, and as the upper plate exhibits no electric appearance, if it has not been previously touched by a conductor, we may conclude that the electrophorus only renders the upper plate electric when it has received or lost a quantity of electricity,

EXPERIMENT CLXVII.

Place one of the small brass conductors with its pith balls on the upper plate, and then put them both on the electrophorus, the balls will immediately separate a little; touch the upper plate with the finger and the divergence ceases; but

but on lifting this plate from the electrophorous by its glass handle the balls diverge with great force, forming a very large angle; on taking a spark from the plate they immediately close. The separation of the balls shews clearly that the upper plate either absorbs a quantity of electricity, or imparts a portion of its natural share to the under one; it also shews that the former, as soon as it is laid on the electrophorus, acquires a small degree of electricity, which it loses on being touched with the finger; but it again becomes electrical when it is separated from the electrophorus.

EXPERIMENT CLXVIII.

Insulate an electrophorus, and suspend a pith ball by a linen thread, in such a manner that it may be about one quarter of an inch from a piece of metal which is connected with the bottom plate; the ball does not move when the upper plate is laid on the electrophorus, but when this is touched by the finger the ball is attracted. As soon as the upper plate is taken off, the inferior metallic coating attracts the ball, but quits it if the coating is touched by the finger. It is also attracted if
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the upper plate is put on before the spark has been taken from it, though it lasts longer and is stronger if the spark is taken before it is placed on the electrophorus.

EXPERIMENT CLXIX.

Electrify the under side of the electrophorus, by connecting the under plate with the conductor of a machine; the upper plate will give strong sparks to the hand, or any other non-electric. Touch the upper plate with one hand, and the under one with the other, a shock will be received. The same effect is produced, if the upper plate is electrified by the machine. See fig. 74.

EXPERIMENT CLXX.

Insulate an electrophorus which is not excited, and place the upper plate upon it, then electrify the under plate by a chain from the prime conductor; take a spark from the chain, and the electrophorus acquires all the properties which are given to it by exciting the upper surface.

EXPERIMENT CLXXI.

Connect the upper plate by a chain with the prime conductor, and electrify it; then take a spark from the chain, and the electrophorus will acquire, as before, the same powers which it gains when the upper surface is rubbed.

EXPERIMENT CLXXII.

The same effect is produced by placing a Leyden phial on the upper plate of an unexcited electrophorus, then charging and discharging it on the plate.

From the three last experiments we learn, that the electrophorus may be put in action by communication as well as by friction.

EXPERIMENT CLXXIII.

Mr. Achard placed the upper plate on an excited electrophorus, and a cube of metal, furnished with a glass handle, on this plate; on taking the cube by its handle from the upper plate, without previously touching it, it attracted a light ball. On repeating this experiment, and touching

touching the upper plate before the cube was taken off, it did not appear in the least electrical.

E X P E R I M E N T CLXXIV.

By examining the electrophorus with small pith balls, we find,

1. That as soon as the upper plate is placed on an electrophorus of wax, it acquires a weak positive electricity; and the contrary, if placed on an electrophorus of glass.

2. That when the upper plate is touched by the finger, it loses all its electricity.

3. When the upper plate is touched by the finger, and removed from the electrophorus, it acquires a strong negative electricity, if the electrophorus is of glass; and a positive electricity, if it is of wax.

The electrophorus may be considered as formed of several horizontal strata; so that when the upper one is excited, either by friction or communication, it is insulated by the inferior strata. Now all insulated electrics preserve their electricity a considerable time, and it is from that cause that the electricity of the electrophorus continues so long.

Insulated and excited glass, induces the negative electricity on bodies brought within the sphere

sphere of its action, while negative electrics, in similar circumstances, produce the positive electricity. Therefore the surface of the electrophorus, ought to communicate immediately a positive electricity, if it is of wax ; the negative, if it is made of glass ; which is perfectly conformable to experiments. But when the upper plate is touched by the finger, the upper surface of the electrophorus ceases to be insulated, and gives the negative electricity to the upper plate, if it is of glass, and the contrary, if of wax, agreeable to the different experiments which are described in Chap. IV.

Electric bodies do not put the fluid in that degree of motion which is necessary to produce the spark, or exhibit the phenomena of attraction and repulsion, while they are in contact with conducting substances, which is the reason why the upper plate exhibits no signs of electricity while it remains in contact with the under one, though they become sensible the instant it is removed from it.

As the theory of this instrument has been deemed very intricate, I have subjoined another explanation of it, which is given by the editors of the Monthly Review.

“ Therefore, (in the case of a glass electrophorus) as it is a case which admits of a somewhat

what easier illustration, the excited plate acts upon the electric matter naturally contained in the upper brass plate, so as to repel a part of its natural quantity from it in form of a spark, at that part where the finger is applied to it. If the brass plate in this state is lifted up by its handle, it will receive a spark from the finger. On being replaced, and the same operation taking place, the same result will be obtained; which may be continued for a great length of time, without diminishing the virtue of the excited electric, which in fact does not part with any of its own electricity, but only repels a part of what is in the upper plate, which is repeatedly restored to it from the earth by the person who makes the experiment."

EXPERIMENT CLXXV.

Place a piece of metal on an excited electrophorus, it may be of any shape; a pair of triangular compasses are very convenient for this purpose. Electrify the piece of metal with the power which is contrary to that of the electrophorus, and then remove it by means of some electric, and afterwards sift upon the electrophorus some finely powdered resin, which will form

form on its surface curious radiated figures. When the plate is negative, and the piece of metal positive, the powder forms itself principally about those parts where the metal was placed; but if the plate is positive, and the spark is negative, the part where the metal touched will be free from powder, and the other parts more covered.

EXPERIMENT CLXXVI.

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 its 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 CLXXVII.

Infulate 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

will not be in the least affected. The similar atmospheres counteract each other; and as no contrary power can take place in the electrometer, it will remain unelectrified. Touch the mug with some conducting substance, and it will immediately attract the balls.

E X P E R I M E N T CLXXVIII.

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, and does not give the least sign of electricity when taken out.

E X P E R I M E N T CLXXIX.

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 its density is diminished in proportion as it spreads
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itself from the surface of the vessel on the extended chain; which is confirmed by the balls diverging again when the chain is let down into the vessel. This experiment affords an easy solution for many of the phenomena of atmospheric electricity, as why the vapour of electrified water gives such small signs of electricity, and why the electricity of a cloud is increased by being compressed or condensed.

E X P E R I M E N T C L X X X .

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.

OF THE ADVANTAGES WHICH MAY BE DERIVED FROM AN IMPERFECT INSULATION, AND OF RENDERING VERY SENSIBLE VERY SMALL DEGREES OF NATURAL AND ARTIFICIAL ELECTRICITY, BY MR. VOLTA.

A conductor, properly constructed for making observations on atmospherical electricity, will seldom affect the most sensible electrometer when the sky is free from electrical clouds; but by

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means

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.

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
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clean dry marble slab, a plate of wood, covered with a coat of varnish, &c. The surface of those bodies not contracting electricity, or if any should adhere to them it soon vanishes, on account of their semi-conducting nature; for which reason they cannot answer the end of an electrophorus, but are fit to be used as condensers of electricity.

Care should be taken however in choosing this plane, that it be not of too free a conducting nature, nor likely to become so by use, it being absolutely necessary that the electricity should find a considerable resistance in pervading its surface. In preparing such a plane, by drying, or otherwise, it is much better to come too near than too far from a non-conductor. A marble slab or board, properly dried, answers well, and is 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 advantage 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 tallow, and any other silk stuff that is not very thick, may be used with equal advantage, if it is slightly warmed. Silk stuffs answer better for this purpose than those made of cotton or wool, and both better than linen. Paper, leather, wood, ivory, bone, and every other sort of imperfect conductors may be made to answer to a certain degree, if they are previously dried, and kept hot during the experiment.

This apparatus is rendered more simple by applying the silk, &c. to the upper plate of metal, which is fixed to the glass handle, instead of the marble or other plate, which now becomes useless; for in its stead, a plane of any kind may be used, as a common wooden or marble table, even not very dry; a piece of metal,

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, as will be evident in the second part.

It is immaterial whether the non-conducting or semi-conducting stratum be laid upon one or the other of those planes; all that is necessary is, that they should coincide together, which renders it proper to use two planes that have been ground together, and one of them varnished. A single metal plate, covered with silk, with three silk strings fastened to it by way of handle, may be conveniently used for ordinary experiments.

To use the apparatus, the upper metal plate must be placed upon the unelectrified plate and in perfect contact with it.

The plates being thus placed, let a wire, communicating with the conductor, be brought to touch the metal plate of the electrophorus, and that only.

The apparatus being left in that situation a certain time, will acquire a sufficient quantity of electricity, but very slowly.

Remove the communicating wire from the metal plate, and, by means of its insulated handle, separate it from the under one; it will now attract a thread, electrify an electrometer, and, if it is strong, will give sparks. &c. though the atmospherical conductor shewed no, or only small, signs of it.

It is not easy to determine the exact time necessary for this apparatus to remain in contact with the conductor, as it will depend on many circumstances; for, if there are no signs of electricity in the conductor, it will require eight or ten minutes, but if it attracts a 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 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 its index to the highest degree, and give a stronger spark; yet it may be plainly perceived, that the condensation is proportionably less in this than in the other case; for this reason the electricity cannot be accumulated beyond the greatest degree; that is to say, when it is increased so much as to be dissipated every way: Therefore, as the electric power, which supplies the condenser, is nearest to the highest degree, the condensation is proportionably less; but in this case the condenser is useless; its principal use being to collect and render sensible that small quantity of electricity which would otherwise remain imperceptible 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 its coated sides with the discharging rod or the hand, appears to be quite deprived of its electricity; yet, if you touch the knob of it with the metal plate of the condenser, (situated upon an imperfect conducting plane) and immediately take up the plate, it will be found to give very conspicuous signs of electricity. But, if just sufficient charge is left in the 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 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 cannot easily be discovered without the condenser, in which case it becomes more than sensible

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ble, and sufficient for the experiments of the inflammable air-pistol, &c.

Secondly. If you have an electrical machine so far out of order that its conductor will not give a spark, nor attract a thread, then let this conductor touch the metal plate of the condenser, and continue in that situation a few minutes, (the machine being still in motion) lift up the metal plate, and you will obtain from it a strong spark.

Thirdly. If the electrical machine acts well, but the conductor is so badly insulated that it will not give a spark, either from its being connected with the walls of the room, or by having a chain from it to the table, let the conductor in this state touch the metal plate of the condenser, while the machine is in action, the plate will afterwards give sufficient strong signs of electricity; which proves the great power this apparatus has of drawing and condensing the electricity.

Fourthly. Where the electrometers are not sufficiently sensible to discover the quantities of excited electricity, those quantities may be readily explored by the condenser. For this purpose, rub those bodies with the metal plate of the condenser, which for this purpose must be naked, and if the plate be then presented to an elec-

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 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

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 phenomena of attraction and repulsion, and especially the degree of elevation of an electrometer correspond,

That the *intensity* of electricity must be inversely proportioned to the *capacity* of the body electrified will be clearly exemplified by the following experiment.

EXPERIMENT CLXXXI.

Take two metal rods of equal diameter, the one a foot, the other five feet long; let the first

first be electrified till the index of the electrometer rises to 60° , then let it touch the other rod; and in that case it is evident that the intensity of the electricity being diffused between the two rods, will be diminished as the capacity is increased; so that the index of the electrometer, which before was elevated to 60° , will now fall to 10° , viz. to one sixth of the former intensity. For the same reason, if the like quantity of electricity was communicated to a rod 60 feet long, its intensity would be diminished to one degree; and on the contrary, if the electricity of the long conductor was contracted into the 60th part of that capacity, its intensity would be increased to 60.

Conductors of different bulk have not only different capacities for holding electricity, but also the capacity of the same conductor is increased and diminished in proportion as its surface is enlarged and contracted; as is shewn in Dr. Franklin's experiment of the can and chain, &c. from which it has been concluded that the capacity of conductors is in proportion to their surface, and not to their quantity of matter.

This conclusion is true, but does not comprehend the whole theory, since even the extension contributes to increase the capacity. In short, it appears from all the experiments hitherto

therto made, that the capacity of conductors is not in proportion to the surfaces in general, but to the surfaces which are free, or uninfluenced by similar or homologous atmospheres; and further, that the capacity of a conductor, neither altered in its form or surface, is increased, when instead of remaining quite insulated, it is presented to another, not insulated; and this increase is more conspicuous, as the surfaces of the conductors are larger and approach nearer to each other.

The above-mentioned circumstances, by which the natural capacity of conductors is greatly augmented, has been overlooked, and therefore no advantage has hitherto been deduced from it. The following experiment will shew this increased capacity in the simplest manner.

EXPERIMENT CLXXXII.

Take the metal plate of an electrophorus, hold it by its handle in the air, and electrify it so, that the index of an electrometer annexed to it may be elevated to 60° , then lower the plate by degrees to a table, or other plane conducting surface, the index will gradually
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fall from 60° , to 50° , 40° , 30° , &c. and yet the quantity of electricity in the plate remains the same, except it is brought so near the table as to occasion a transmission of the electricity from the former to the latter; at least, it will remain as near the same as the dampness of the air, &c. will permit. The decrease of intensity is owing to the increased capacity of the plate, which is now not insulated, or *solitary*, but *conjugate*, or communicating with another conductor: for let the plate be gradually removed from the table, the electrometer will rise again to its former station, namely, to 60° ; excepting the loss that the air, &c. may have occasioned during the experiment.

The reason of this phenomenon is easily derived from the action of electric atmospheres. The atmosphere of the metal plate, which for the present I shall suppose electrified positively, acts upon the table, or other conductor, to which it is presented; so that the electric fluid in the table retiring to the remoter parts of it, becomes more rare in those parts which are exposed to the metal plate, and this rarefaction increases the nearer the electrified metal is brought to the table, if the metal plate is electrified negatively, the contrary effects take place. In short, the parts which are immersed
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in the sphere of action of the electrified plate, by contracting a contrary electricity, give the electricity of the metal plate an opportunity to expand itself, and will thus diminish its intensity, as is shewn by the depression of the electrometer.

The two following experiments will throw more light upon the reciprocal action of the electric atmospheres.

EXPERIMENT CLXXXIII.

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 react 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

ductor will shew less intensity than a more compact one, supposing their quantity of surface and electricity to be the same; because the homologous atmospheres of their parts interfere less with each other in the former than in the latter case, and of course, as their action is less, the re-action is also less.

EXPERIMENT CLXXXIV.

Electrify one of these flat conductors positively, the other negatively, and the effects will then be just the reverse of the preceding, viz. the intensity of their electricities will be diminished, because their capacities, or their power and facility of expanding are increased the nearer the conductors come to each other.

Apply the explanation of this last experiment to that mentioned before; viz. the bringing the electrified metal plate towards a conducting plane, which is not insulated; for, as this plane acquires a contrary electricity, it follows that the intensity of electricity in the metal plate must be diminished, and the annexed electrometer is depressed according as the capacity of the plate is increased, or as the density of its atmosphere is diminished; and consequently the

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 CLXXXV.

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, then 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

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inferior plane. But if, in this situation, the inferior plane be touched so as to cut off the insulation for a moment, then it will acquire the contrary electricity, and the intensity in the metal plate will be diminished.

If the inferior plate, instead of being insulated, were itself a non-conducting substance, then the same phenomena would happen, viz. the intensity of the electrified metal plate laid upon it would not be diminished. This, however, is not always the case, for if the said inferior non-conducting plane is very thin, and is laid upon a conductor, then the intensity of the electrified metal plate will be diminished, and its capacity will be increased by being laid upon the thin insulating stratum: as in that case, the conducting substance, which stands under the non-conducting stratum, acquiring an electricity contrary to that of the metal plate, will diminish its intensity, &c. and then the insulating stratum will only diminish the mutual action of the two atmospheres more or less, according as it keeps them at greater or smaller distances from each other.

The intensity or electric action of the metal plate, which diminishes gradually as it is brought nearer and nearer to a conducting plane not insulated, becomes almost nothing when
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the plate is nearly in contact with the plane, the compensation or natural balance being nearly perfect. Hence, if the inferior plane only opposes a small resistance to the passage of the electricity, (whether such resistance is occasioned by a thin electric stratum, or by the plane's imperfect conducting nature, as is the case with dry wood, marble, &c.) that resistance, joined to the interval, however small, that is between the two plates, cannot be overcome by the weak intensity of the electricity of the metal plate, which on that account will not dart any spark to the inferior plane, (except its electricity were very powerful, or its edges not well rounded) and will rather retain its electricity; so that being removed from the inferior plane, its electrometer will nearly recover its former height. Besides the electrified plate may even come to touch the imperfectly conducting plane, and may remain in that situation for some time; in which case, the intensity being reduced almost to nothing, the electricity will accordingly pass but slowly to the inferior plane. But the case is different, if, in performing this experiment, the electrified metal plate touches the inferior plane edgewise, for then its intensity being greater than when it is laid flat, as appears by the elec-

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trometer, the electricity easily overcomes the small resistances, and passes to the inferior plane, even across a thin stratum, because the electricity of one plane is balanced by that of the other, only in proportion to the quantity of surface which they oppose to each other within a given distance; so that when the metal plate touches the other plane in flat and ample contact, its electricity is not dissipated. This apparent paradox is clearly explained by the theory of electric atmospheres.

'Tis still more like a paradox, that neither touching the metal plate with a finger or piece of metal will deprive it of all its electricity, while standing upon the proper plane; so that it generally leaves it so far electrified that when separated from the plane, it will give a spark. Indeed, this phenomenon could not be explained on the supposition, that the finger or metal were perfect conductors. But, since we do not know of any perfect conductor, the metal or finger oppose a sufficient resistance to retard the immediate dissipation of the electricity of the plate, which is in that case actuated by a very small degree of intensity, or power of expansion; so that, suppose for instance, the piece of metal or finger touching the plate took off so much of its electricity as to reduce the

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the intensity of the remainder to the 50th part of a degree, this remaining electricity would be then nothing ; but when the plate, by being separated from the inferior plane, has its capacity so far diminished as to render the intensity of its electricity 100 times greater, then the intensity of that remaining electricity would become of two degrees or more; viz. sufficient to afford a spark.

Having considered in what manner the action of electric atmospheres modifies the electricity of the metal plate in its various situations, we shall now consider the effects which take place when the electricity is communicated to the metal plate, whilst standing upon a metal plane. As the whole business has been proved in the preceding pages, it is easy to deduce the applications from it; nevertheless, it will be useful to exemplify it by an experiment.

E X P E R I M E N T C L X X X V I .

Suppose a Leyden phial or a conductor, so weakly electrified that its intensity is one half a degree, or even less: if the metal plate of the condenser, when standing upon its proper plane was to be touched with that phial or con-

ductor, it is evident that either of them would impart to it a quantity of its electricity, proportional to the plate's capacity, viz. so much as should make the intensity of the electricity of the plate equal to that of the electricity in the conductor or 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 acquires 100 times more electricity from the phial or conductor. It naturally follows, that when the metal plate is removed from the proper plane, its capacity being lessened so as to remain equal to the 100th part of what it was before, the intensity of its electricity must become $.50^{\circ}$, 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 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.

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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 its plane, the electricity in it appears much condensed and vigorous; so when the same plate contains a small quantity of electricity, such as cannot give a spark or affect an electrometer, that electricity may be rendered very conspicuous by communicating it to another small plate or condenser.

Mr. Cavallo first thought of this improvement, by reasoning on Mr. Volta's experiments. He made a small metal plate not exceeding the

size of a shilling. This second condenser is of great use in many cases where the electricity is so small as not to be at all, or not clearly, observable by one condenser only, as has been fully proved. Sometimes the usual metal plate of a condenser acquires so small a quantity of electricity, that being afterwards taken from the inferior plane, and presented to an extremely sensible electrometer, made by Mr. Cavallo, it did not affect it. In this case, if the said plate, thus weakly electrified, was made to touch the other small plate properly situated, and was afterwards brought near an electrometer, the electricity was then generally stronger than was sufficient merely to ascertain its quality.

Now if, by the help of both condensers, the intensity of the electricity has been augmented 1000 times, which is by no means an 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 communicated to an electrometer, it will hardly affect that instrument, and yet is sufficient to afford conviction that the metal can be electrified by the friction of a person's hand.

Before

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.

C H A P. XII.

OF ATMOSPHERICAL ELECTRICITY.

IT is now universally acknowledged by every philosopher, that the electric fluid is diffeminated 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, its motion must be exceeding free, and hence capable of the greatest effects: because it can be moved from one place to another with extreme ease and rapidity, and in great quantities; and if, as many philosophers believe, the electric fluid is that ether or 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

that in proportion as air is loaded with it, it resists less the motion and diffusion of the electric fluid: consequently, if vapour rises to a great height, it becomes a conductor and canal of communication between this immense reservoir, this ocean of free electric fluid, and the entire mass of our globe. If then this fluid is more restrained at one part of our globe than it is in corresponding parts of the higher regions the vapours will be the medium to restore the equilibrium. But this equilibrium will not last long, for it is natural to suppose this immense fluid subject to a flux and reflux, currents, &c. which will alter its local density. Thus also this fluid which is contained in our globe, cannot be long uniformly spread through its mass, as there are ten thousand agents, which will either accumulate or 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 phenomena which it explains. It is the only one that accounts for the following fact, that vapours never rise to a great height
without

without producing the most terrible meteors. All considerable volcanic productions are accompanied with lightening. 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 lightening *, which sometimes seems to proceed from the higher regions, sometimes from the column itself. Hail, which necessarily supposes the ascension of vapour to a considerable height, is always accompanied with electricity. The aurora borealis is also electrical; its light seems to be produced by the electric fluid, at the instant it is condensed in passing in the columns of elevated vapour.

Water-spouts, 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

* The younger Pliny observed these lightnings in the eruption which killed his uncle. Sir William Hamilton has also observed them several times.

† Sauffure's *Essais sur l'Hygrometric*, p. 275.

many years accurately observed the various changes in the electricity of the atmosphere, and their relation to the other phenomena of the weather. His apparatus was admirably well adapted for this purpose, and superior to any thing 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,

chimney; the other end was fastened to the top of a cherry-tree. The extremities of the wire were insulated, and covered with a small umbrella of tin. Another wire was brought from this, (through a thick glass tube, coated with sealing-wax) into the room; by which means, continual information of the state of the electricity in the exploring wire was obtained. He connected with this wire a small slip of metal, on each side of which was a small pith ball, one line 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 Sauffure 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.

* Faujas de St. Fond, Description des Expériences Aérostatiques, tom. II. p. 271.

In serene weather, the wire, after being touched, will take a minute or longer before it again shews signs of electricity; though, at other times, it will become electrified in the space of a second.

The electricity during serene weather is always positive. There are few instances in which it is negative, and then it is brought over by the wind from some part of the atmosphere, (perhaps very distant from the place of observation) where there is either fog, snow, rain, or clouds. The whole series of observations which P. Beccaria has made confirm this position. He seems to have met with only three or four instances to the contrary.

Dr. Franklin has observed, that the clouds are sometimes negative, which is certainly true; because they will at times absorb, at and through the apparatus, a large and full bottle of positive electricity, of which the apparatus could not have received and retained the hundredth part. And it is easy to conceive, how a strongly charged large positive cloud may reduce smaller clouds to a negative state.

The electricity of the atmosphere is very much connected with the state of the air, as to moisture and dryness; so that it is necessary to attend to the hygrometer, in order to form a
proper

proper judgment of the different degrees of electricity at different times. That invented by Mr. Coventry, which is made of hatters' paper, will answer best; it is very sensible, absorbs moisture soon, and parts with it easily. Comparative observations may also be made with it. It is also necessary to place a thermometer near the hygrometer, to ascertain what quantity of moisture the air can keep in solution with a given degree of heat: though this object will more probably be obtained by observing accurately the quantity of moisture 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

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be observed between the finger and the plate of brass to which they are affixed *.

The electricity, when the weather clears up, is always positive. When the weather is clearing up, and becomes dry quickly, the electricity rises to a great degree of intensity, and affords frequent opportunities for repeating the observations. It sometimes happens, that the electricity, caused by the clearing up of the weather, continues in its state of intensity for a long while; and also, after being interrupted, it begins afresh. These accidents seem to be owing to the electricity being brought over by the wind from great distances.

P. Beccaria says, that whenever he observed that the thick low clouds which were over his head began to break, and the rare even clouds, which are above the former, became dilated, that the rain ceased, and the balls diverged with positive electricity, he always wrote down CERTAIN TENDENCY TO CLEAR WEATHER.

Prior Ceca says, that a strong positive electri-

* 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.

city 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 clouded over the place of observation, and a high cloud is formed, without any secondary clouds under it, and that 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 foretells 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 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. Henly 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

returns to its former state. When many whitish clouds, like locks of wool, keep over the wire, sometimes uniting with, and then separating from, each other, thus forming a body of considerable extent, the positive electricity commonly increases. In all the above circumstances the positive electricity never changes to a negative one.

The clouds which lessen the electricity of the exploring wire are those which move; though those that are low seem also to have the same effect.

OF THE DIURNAL ATMOSPHERICAL ELECTRICITY.

In the morning, when the hygrometer indicates a degree of dryness equal to, or little less than that of the preceding day, an electricity takes place before the sun rises; which is manifested by junctions, adhesions, or even a divergence of the balls, and is proportional to the dryness of the air, and the smallness of its difference from that of the preceding day. If this state of dryness does not obtain, no discernible electricity will be perceived before, or even for a little while after, the rising of the sun.

As the air is generally damp in the night, electricity is seldom observed before the sun rises. During three months observations P. Beccaria found the electricity before the sun rose only eighteen mornings; and from the whole of his numerous observations it appears, that the appearance of electricity in winter before sun-rise is more frequent than in the summer, especially if the dampness from hoar-frost is prevented from affecting the apparatus.

In the morning, as the sun rises higher, the electricity, whether it began before sun-rise or only after, gradually increases. This gradual increase of the morning electricity begins sooner if the hygrometer continues after sun-rise to indicate a greater degree of increasing dryness. The intensity and the rise of the electricity (after it has been annihilated by touching the exploring wire) lasts in serene days, in which no impetuous wind takes place, and the hygrometer is stationary at the highest degree it has attained that day, till the sun draws near the place of its setting. When the sun is near setting, and in proportion as the hygrometer absorbs the moisture, the intensity of the daily electricity lessens.

Though the hygrometer may indicate equal degrees of dryness at twelve o'clock, in different

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ent days, yet the electricity will appear sooner after being destroyed on some days than on others; and this is in a great measure proportioned to the increase of heat. The electricity moreover commences on such days later in the morning, and falls sooner in the evening.

The friction of winds against the surface of the earth is not the cause of atmospheric electricity. Impetuous winds lessen the intensity of the electricity in clear weather. If they are damp they lessen its intensity in proportion to the diminution they cause in the exactness of the insulation both of the wire and atmosphere.

OF THE ELECTRICITY PRODUCED BY THE EVENING DEW.

In cold seasons, if the sky is clear, little 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 electri-

city intirely fimilar to the former arifes as foon as the fun has fet; only its intenfity is not fo constant; it begins with greater rapidity, and ends fooner.

If, under the above circumftances refpectively, the general drynefs of the air happens to be lefs, the electricity that riles in the evening, when the dew begins, is lefs in proportion to the diminutions of the exactnefs of the infulation of both the exploring wire and the atmofphere; but correpondently to the greater quantity of dew, the frequency of the electricity is greater.

The electricity of dew feems to depend on the quantity of dew, and to follow in its various changes, proportions fimilar to thofe which take place between the electricity of calm mild rain, and that of rainy and ftormy weather, and varies alfo according to the feafons.

As rain, fhowers, the Aurora Borealis, and the zodiacal light, have a tendency to appear for feveral fucceffive days with the fame characteristic accidents, fo the electricity of dew feems to have as it were an inclination to appear for feveral evenings fucceffively with the fame characters.

EXPERIMENT CLXXXVII.

Let the air in a well-closed room be electrified; that is to say, the moisture and other vapours diffused in it: then let a bottle, filled with water colder than the air in the room, and insulated on a tube of glass, be raised pretty high in this room. Care must be taken to preserve the insulation of the glass, with warm cloths. The electric signs that will arise in two threads suspended to such bottle will exactly represent the electricity of dew; and they will exhibit the different manner after which this electricity takes place, according as the electrified vapours in the room are more or less rare; as the difference between the heat of the air in the room, and that of the water in the bottle is less or greater, and the insulation of the bottle is more or less exact.

In a thunder-storm Mr. Ronayne observed, that the flashes would cause sudden changes. Sometimes the electricity would be extended, sometimes diminished; at other times increased, and sometimes even changed to the contrary again, though none was perceived before; it would come on suddenly with a flash of lightning

ening. 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; that 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,

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 overhead. 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 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,

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gn 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 its 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 its lowest extremity, which touches the inside non-electric coating. A glass handle is fixed to the ball on the wire which passes into the foregoing glass tube;

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 un insulated. When the electricity of the atmosphere is observed with this instrument, thrust the pin T into the cork D, and hold the rod by the lower end A; place it out of a window at the upper part of the house, raising the end of the rod
with

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.

Fig. 81 is an electrometer for rain, contrived by Mr. Cavallo. A B C T is a strong glass tube, about two feet and a half long, having a tin funnel D E cemented to its extremity, which funnel defends part of the tube from the rain. The outside surface of the tube from A to B is covered with sealing-wax, and so is the part of it which is covered by the funnel. F D is a piece of cane round which brass wires are twisted in different directions, so as to catch the rain easily, and at the same time to make no resistance to the wind. This piece of cane is fixed into the tube, and a small wire proceeding from it goes through the tube, and communicates with the strong wire A G, which

is thrust into a piece of cork, fastened to the end A of the tube. The end G of the wire A G is formed into a ring, from which a sensible pith ball electrometer is to be suspended. This instrument is fastened to the side of a window frame, where it is supported by strong brass hooks at C B; which part of the tube is covered with a silk lace, in order to adapt it better to the hooks. The part F L is out of the window, with the end F elevated a little above the horizon. The remaining part of the instrument comes through a hole in one of the lights in the sash, within the room, and no more of it touches the side of the window than the part C B. When it rains, especially in passing showers, this instrument is frequently electrified; and by the divergence of the electrometer, the quantity and quality of the rain may be observed without any danger of a mistake. With this instrument, in rainy weather, Mr. Cavallo has been able to charge a small coated phial at the wire A G. It should be fixed in such a manner that it may be easily taken off from the window, and replaced again, as occasion requires; as it will be necessary to clean it often, particularly when a shower of rain is approaching.

DESCRIPTION OF A SMALL PORTABLE ATMOSPHERICAL ELECTROMETER, INVENTED BY MR. CAVALLO.

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 its 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 intirely 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 wire is cemented, which, with its under extremity, touches the flat piece of ivory H, fastened to the tube by means of a cork; the upper extremity of the wire projects about a quarter of an inch above the tube, and screws into the brass cap E F, which cap is open at the bottom, and serves to defend the waxed part of the instrument from 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

and communicating with the brass bottom A B. They serve to convey that electricity which, when the balls touch the glass, is communicated to it, and, being accumulated, might disturb the free motion of the balls.

To use this instrument for artificial electricity, electrify the brass cap by an electrified substance, and the divergence or convergence of the balls of the electrometer, at the approach of an excited electric, will shew the quality of the electricity. The best manner to electrify this instrument is to bring excited wax so near the cap that one or both of the corks may touch the side of the bottle CDMN, after which they will soon collapse and appear un-electrified. If now the wax is removed, they will again diverge, and remain electrified 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 its case, and hold it by the bottom A B to present it to the air a little above his head, so that he may conveniently see the balls P, which will immediately diverge if there is any electricity; i. e. whether positive or negative may be ascertained, by bringing an

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excited

excited piece of sealing-wax or other electric towards the brass cap E F.

GENERAL LAWS DEDUCED FROM THE EXPERIMENTS PERFORMED WITH THE ELECTRICAL KITES.

1. The air appears to be electrified at all times. Its electricity is constantly positive, and much stronger in frosty than in warm weather; but it is by no means less in the night than in the day time.

2. The presence of the clouds generally lessens the electricity of the kite: sometimes it has no effect upon it, and it very seldom increases it.

3. When it rains the electricity of the kite is generally negative, and seldom positive.

4. The Aurora Borealis seems not to affect the electricity of the kite.

5. 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

higher than 20° , the person who takes the spark will feel the effects of it in his legs; it appears more like the discharge of an electric jar, than the spark taken from the prime conductor of an electrical machine.

6. 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 a 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° .

7. 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 surprizingly quick to its usual place, but in dry or warm weather it rises exceedingly slow.

It appears, from the observations which have been made on the electricity of the atmosphere, that nature makes great use of this fluid 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 elec-

tricity of the clouds and of the rain continues to increase till that part of the autumn in which the last fruits are gathered.

2. It is this fluid which supplies common fire with that moisture by the help of which it actuates and animates vegetation: it is the agent that collects the vapours, forms the clouds, and is then employed to disorder and dissipate them in rain.

3. From the same principle may be explained the proverb, that *No watering gives the country so smiling a look as rain*. The clouds of rain, by extending their electric atmosphere to the plants, dispose the pores of the latter to receive with greater facility the water which is impregnated with this penetrating and dilating fluid. Besides, it is natural to suppose, that the positive electricity which continually prevails in serene weather, will contribute to promote vegetation, since this has been found to be the effect of even artificial electricity.

OF THE IMPERFECTIONS OF METEOROLOGY,
SO LONG AS BAROMETRICAL, THERMOMETRICAL,
AND HYGROMETRICAL OBSERVATIONS ARE NOT ACCOMPANIED WITH THE
REGULAR OBSERVATION OF THE ELECTRICITY OF THE ATMOSPHERE, OF THE ELECTRICITY OF RAIN, SNOW, MISTS, AND AQUEOUS METEORS IN GENERAL. BY MR. ACHARD.

As it is now clearly ascertained, that electricity is a cause of various meteorological phenomena, it is rather surprizing that philosophers have not perceived the absolute necessity of joining an instrument by which observations may be made on the electricity of the atmosphere, to those which indicate its weight, heat, and humidity.

Without considering in this place the different proofs of the influence of electricity on meteors, it will be sufficient to remark, that we cannot attain to an adequate knowledge of any phenomena, occasioned by the concurrence of various causes, without being acquainted with them all; for if any one is neglected, it will be absolutely impossible thoroughly to explain the phenomena. If electricity is not the sole cause

of several meteorological appearances, it is undoubtedly concerned more or less in their formation; so that by neglecting to observe it, as well as the barometer, &c. we lose the fruits of other, even very exact, meteorological observations.

The influence of electricity on vegetation is proved by a set of observations made by different philosophers; but it evidently appears that the botanic meteorological observations alone will never be so useful as might be expected, till we unite those made by an instrument which will indicate the electric state of the atmosphere, to those made with other instruments. It is owing to this cause, perhaps, that it is impossible to draw any conclusion from the botanical meteorological observations of Messrs. Gautier and Duhamel, which were continued from 1751 to 1769.

Mr. Achard has had an opportunity of making a few observations, but they were sufficient to convince him of the intimate 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 its simplicity, is almost preferable

able 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 was 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 other day he found the air electrical during the whole day, but always strongest a little before sun-set, a short time after which it began again to diminish.

If in serene weather the sky became suddenly cloudy, the electrometer indicated continual changes in the electricity of the atmosphere; sometimes increasing, then disappearing, then re-appearing; in which case it had generally changed from positive to negative, or *vice versa*. In windy weather he found it difficult to observe with the electrometer, on account of the continual motion of the balls. It seemed to vary considerably when the air was heavy, but

not windy. When the weather was very calm, and the sky without clouds, the electrometer did not alter in the least, except towards sun-set, when it increased in a small degree.

It is remarkable, that in those days in which he observed no electricity in the air, there was no dew at night; while on the other nights, it fell in greater or less quantities. He does not think those observations are sufficient to determine that the dew is occasioned by electricity, but it may, he thinks, be fairly inferred, that the elevation and fall of the dew is obstructed or promoted by the electricity of the air. It is easy to point out in what manner electricity may produce the effect. Let us suppose the air to be either positively or negatively electrified, but the surface of the globe where we are not to be so; the aqueous and volatile parts of the vegetables exhaled by the rays of the sun, and suspended in the air, will become electric by communication. The air cooling by the absence of the solar heat, will not, after the setting of the sun, retain the aqueous particles with the same force; and these being attracted by the non-electric bodies which are on the surface of the earth, their superficies will be covered with dew. Again, let us suppose that the surface of the earth is electrical, but that
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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 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

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 minutes the fog ceased altogether, and fell in form of a fine rain; and though it was very thick, disappeared in about seven minutes. It is also very probable that rain is occasioned by electricity; and of this we shall be convinced, if we consider the attractions and repulsions that the terrestrial or atmospheric electricity must occasion, as well between the surface of the globe and the vapours contained in the air, as between the particles of vapour which always necessarily tend to disperse or unite the aqueous particles which swim in the atmosphere, and to bring them nearer, or carry them farther from, the earth.

Having proved the necessity of combining observations on the electricity of the atmosphere with other meteorological observations, Mr. Achard proceeds to describe the properties requisite in a good atmospheric electrometer, the want of which accounts for the neglect and supineness of philosophers on this subject.

NECESSARY REQUISITES IN AN ATMOSPHERICAL
ELECTROMETER.

1. It should be easy in its use.
2. It should not only indicate that the air is electrical, but in what degree.
3. It is necessary that we may learn whether it is positive or negative.
4. That the observer should be in no danger in stormy weather.
5. That it be portable.

The number of difficulties which oppose the construction of an instrument which will unite all these advantages are very considerable. The greatest is to insulate the metal which receives the electricity from the air, so that rain may not establish a communication between it and the earth, and that the insulation is sufficiently perfect to prevent too quick a dissipation of the electricity received by the metal. Mr. Achard does not pretend that he has surmounted all these difficulties, but after several trials he has contrived an instrument sufficiently portable, easy to observe with, and that without danger.

DESCRIPTION OF THE PORTABLE ATMOSPHERICAL ELECTROMETER, CONTRIVED FOR THE PURPOSES ALREADY MENTIONED.

This instrument is composed of a hollow and truncated cone of tin, whose upper end is open, and which is closed at bottom by a plate of the same metal. This plate is covered, in the inside of the cone, with a layer of rosin two inches thick : to the lower surface of this layer of rosin a tube of tin is cemented, which, when it is placed on a wooden pedestal, supports the cone in such a manner, that the great base is horizontal, and turned downwards; the rosin insulates the cone perfectly, and, when the latter becomes electric, prevents the loss of its electricity by transmission. The cone must be high enough, and its inferior base must exceed far enough, in diameter, its superior extremity, to prevent the rain, even though it should fall in an oblique direction, from wetting, either in its fall, or by rebounding from the pedestal, the lower surface of the rosin-layer, with which the bottom of the truncated cone is internally covered : otherwise the cone would cease to be insulated, and the electrometer would be changed into a conductor. On the
truncated

truncated part of the cone Mr. Achard fastens a square iron branch, on which he places a thermometer and two electrometers; the one very light, and thus capable of being set in motion by small degrees of electricity; the other heavier, and which, consequently, only rises when the electricity becomes too strong to be measured by the light electrometer. Besides these two electrometers, Mr. Achard tied to the iron bar a thread, which indicates, by its rising, the smallest degrees of electricity: the whole is inclosed in a receiver of glass, open above and below; the base of this receiver is also insulated with rosin, that it may not derive any electricity from the tin cone; the remaining space of the upper part of the receiver, between the bar of metal, which passes through it, and the glass, is likewise filled with rosin, to prevent the communication of electricity to the receiver; to preserve this rosin from rain, which, by moistening it, would form a communication between the receiver and the bar, it is covered over with a glass funnel, through which the bar passes, and which hinders the rain from falling on the rosin. This receiver is also indispensably necessary to prevent the action of the wind upon the electrometers, which would render the accurate observation of them impossible.

fible. At the end of the metal bar, which passes through the receiver, hollow tin pipes may be placed, of a small diameter, to render them as light as possible, and they may be raised to the height of 10, 20, or 30 feet. The upper end of the pipe terminates in an iron point, extremely sharp and well gilt; the gilding is necessary to hinder the point, which must be always even and smooth, from contracting rust. With respect to the elevation that it may be proper to give to the tin-pipe, this must vary with the height of the buildings or trees in the different places where observations are made; for the height of the pipe must always exceed, at least by six feet, the elevation of all the bodies that are near it. Mr. Achard joins a thermometer to this machine, which may be observed at the same time, and be the means, perhaps, of discovering the relations, if any there be, between electricity and the temperature of the air. A barometer and hygrometer may, with facility, be added to this instrument for the same purpose.

In order to know whether the electricity of the air be positive or negative, Mr. Achard suspends a ball of cork, by a linen thread, on the wire which communicates with the iron bar, and which passes through the rosin, with
which

which the base of the truncated cone is covered. The wire must be of such a length, that bodies positively or negatively electrical may be commodiously brought near the cork-ball, which is suspended on it; and it is according as these bodies attract or repel the ball, that the observer learns whether the electricity which the instrument has received from the air, be positive or negative.

That the observer may be in no danger from sudden accumulations of electricity, which sometimes happen, Mr. Achard fastens to the base of the pedestal an iron bar, which not only communicates with, but even enters into, the ground, several feet deep. This bar, whose upper part terminates in a round knob or ball, must be only at the distance of an inch from the cone. When the electrical fluid is so accumulated that the instrument can no longer contain it, it will discharge itself against this metal bar, which will conduct it under ground. The same thing would happen, if the lightning fell upon the instrument, and the observer would be in no sort of danger, even at the distance of a few feet. When the instrument is placed in a garden, this method of forming a communication with the ground is subject to no inconveniency; but if it should be judged proper to employ
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the instrument in a house, (which may be done by making the tin pipe pass through a hole in the roof, and placing the instrument in a garret) the manner above-mentioned of forming its communication with the earth would not be so easily executed: in this case, the communication must be effected by means of a bar of metal descending from the garret to a depth of some feet under ground; and for greater security against the too great proximity of a thunder-storm, it would be proper to place the metallic bar in contact with the cone of tin: thus the instrument would become a real conductor, which, instead of exposing the house to danger, would, on the contrary, preserve it from all the accidents that are occasioned by lightning.

When the instrument is placed in a garret, or on the platform of a house, no inconvenience is to be apprehended from ascending dews; but when it is placed in a garden, the dew adheres to the rosin which covers the truncated base of the cone, and forming thus a communication between the cone and the earth, makes the instrument lose the electricity with which it may have been charged. To prevent this accident, it is necessary to pave the ground on which the instrument is placed, and THAT in such a manner, that the pavement may extend itself

on all sides, at least two or three feet beyond the circumference of the lower base of the cone: the rising of the dew, which by adhering to the rosin might damage the instrument, will be thus effectually prevented.

When the air is electrical, it must necessarily communicate its electricity to the vapours which it contains. This is evident from the formation of lightning, which is not produced by the discharge of the electrical matter of the air, but by that of the vapours which float in the atmosphere. Hence it follows, that rain, snow, hail, mist, and dew, must be very often electric. As it appears to Mr. Achard a matter of great consequence to know and observe exactly the electricity of those meteors, he has constructed a machine that is adapted to discover both its nature and degree. This machine is composed of a truncated tin cone, closed at the top, open at bottom, and insulated upon a pedestal, like that of the machine employed to measure the electricity of the air. In the center of the upper truncated part of the cone, Mr. Achard fixes an iron bar terminated by a ball; he covers the whole with an insulated glass receiver, high enough to have its summit at the distance of three inches from the ball which terminates the iron bar, to which he

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fastens

fastens a very SENSIBLE electrometer, and also a linen thread to discover the smallest degrees of electricity. As this instrument is but little elevated, and has no pointed extremity, it is not easily charged with the electricity of the air, which at such a degree of proximity to the earth is always imperceptible; but rain, snow, hail, mist, and dew, if they are electrical, will render it also electrical by falling upon the cone; the degree of electricity is ascertained by the electrometer, which is under the receiver; and in order to know whether it be positive or negative, the observer has only to employ the method indicated above, in our account of the instrument used to measure the electricity of the air. Besides the use of this instrument in discovering the electricity of aqueous meteors, it may still serve farther purposes: it may be highly useful to compare it with the atmospheric electrometer, in order to discern the true principle of the electricity with which it is charged, and to see whether it proceeds immediately from the air, or from the heterogeneous bodies that are suspended in the atmosphere; for the atmospheric electrometer may also become electrical by rain, snow, hail, or mist; and the comparing these two instruments is the only method that occurs to Mr. Achard by which

which we can know, whether it receives its electricity directly from the air, or by the intervention of bodies (indued with a CONDUCTING power) which are diffused in it. If, during rain, hail, snow, or mist, the atmospherical electrometer is ELECTRICAL, while THAT which indicates the electricity of aqueous meteors is NOT so, we may conclude, with certainty, that the electricity of the former proceeds only from the air; if, on the contrary, they are both electrical, it must then be inquired, whether they be so in the same degree; if this be the case, it is only to the rain or snow, &c. that the electricity must be attributed. I need not observe (concludes Mr. Achard) that when there is neither rain, snow, hail, or mist, the atmospherical electrometer will always indicate the electricity of the air.

CHAPTER XIII.

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.

Elec-

Electricity acts strongest upon the fluids when the vessels which contain them are non-electrics. The evaporation was greatest in the most open vessels, but did not increase in proportion to their apertures. It does not make any liquor evaporate through the pores either of metal or glass.

To extend these principles further, the 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 its motion in a small degree.

If the tube is so far capillary that the water only issues from it in drops, the electrified jet becomes a continued stream; it will even be divided into several smaller ones, and its motion is considerably accelerated; the smaller the diameter of the tube, the greater is the acceleration. When the surface is wider than one tenth of an inch, electricity seems rather to retard the motion of the fluid.

From some very accurate experiments made by Mr. de Sauffure 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.

E X P E R I M E N T C L X X X V I I I .

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.

E X P E R I M E N T C L X X X I X .

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

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 CXC.

Place a metal basin on an insulating stand, and connect it with the prime conductor; then pour a small stream of water into the basin, which in the dark will have a beautiful appearance, as the stream will be divided into a great number of lucid drops.

EXPERIMENT CXCI.

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 CXCH.

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.

E X P E R I M E N T CXCIII.

The knob of a charged jar will attract a drop of water from a faucer, &c. This drop, the moment the bottle is removed from the faucer, 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.

E X P E R I M E N T CXCIV.

Discharge a battery through a drop of water, previously placed on the knob of one of its bottles; the whole will be instantly exploded into vapour; the sparks will be much longer than common, and more compact.

Beccaria

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 CXC.V.

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 CXC.VI.

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.*

* Nicholson's Introduction to Philosophy.

EXPERIMENT CXCVII.

Stick a piece of sealing-wax on the conductor, in such a manner that it may be easily set on fire by a taper ; while it is flaming turn the cylinder, the wax will become pointed and shoot out an almost invifible 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 fheet of paper, the paper will be covered by them in a very curious manner, and the particles of the wax will be fo far subdivided as to refemble fine cotton. To faften the piece of wax conveniently to the conductor, ftick it firft on a fmall piece of paper, then twift the end of the paper fo 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 CXCVIII.

Infulate a fountain made by condensed air, and which emits only one fream ; electrify the fountain and the fream will be feperated into
a great

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 CXCIX.

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,

C H A P. XIV.

OF THE ELECTRIC LIGHT IN VACUO.

E X P E R I M E N T CC.

TAKE a tall dry receiver, and insert in the top, with cement, a wire with a rounded end, then exhaust the receiver, and present the knob of the wire to the conductor, and every spark will pass through the vacuum in a broad stream of light, visible the whole length of the receiver, moving with regularity, unless it is solicited and bent out of its way by some non-electric, then dividing itself into a variety of beautiful rivulets, which are continually dividing and uniting in a most pleasing manner. If the vessel is grasped by the hand, at every spark a pulsation is felt, like that of an artery, and the fire bends itself towards the hand. This pulsation is even felt at some distance from the receiver, and in the dark, a light is seen between the hands and the glass. The streams of light pass silently through the receiver, because the air is removed by whose vibration sound is produced.

From

From some experiments made several years since by Mr. Wilson, with an excellent air-pump of Mr. Smeaton, he observed, that very small differences of air occasioned very material differences in the luminous effects produced by the electric fluid; for when all the air was taken out of the receiver, which this pump at that time was capable of extracting, no electric light was visible in the dark. Upon letting in a little air by a stop-cock, a faint electric light was visible, and by letting in a little more air increased the light, which again decreased on letting in more air; till at last, on admitting great quantities, it intirely vanished. By this experiment it appeared, that a certain limited quantity of air was necessary to occasion the greatest luminous effect.

EXPERIMENT CCI.

Fig. 82 represents an exhausted receiver, standing on the plate of an air-pump, *ab* an electrified wire discharging a stream *bc* 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

be given to the fluid on the outside to escape, the fluid within will be impelled to that part, as at *def*. It has been inferred from this experiment, that no repulsive power exists between the particles of the electric fluid; because, if it was in itself really elastic, or endowed with a repulsive power of its own, it is not probable it could pass in an uninterrupted stream, as at *bc*, when the resistance was taken off; it would then spread wider, and display its elastic power.

It is more consistent, says Dr. Watson, to suppose, that the repulsion of these particles which is seen in the open air, is occasioned by the resistance of the air, and not to any natural tendency of the electricity itself.

By considering the experiments made with the electric fluid IN VACUO, we attain a clear idea of the resistance the air continually makes to its passage, and see that the divergence of its rays is not to be attributed to an imaginary repulsion, but to the resistance of the ambient air, for the divergence ceases, and the rays unite when this resistance is removed.

EXPERIMENT CCII.

Before the air was exhausted from the receiver, if the wire at the top of it was electrified, a diverging

verging brush proceeded from it, about an inch long, but little of the fluid passing off, and even that little requiring a strong impulsive force to push it forward. On exhausting the receiver the following changes took place: first, the rays of the brush became longer; secondly, the rays diverged less, were fewer in number, and the size of the remaining rays was increased; thirdly, they all united at last, and formed a continued column of light, from the wire to the plate of the air pump.

From this experiment it is clear, that the air is the agent by which, with the assistance of other electrics, we are able to communicate electricity on electrics, as well as non-electrics; for when this is removed, the fluid pervades the vacuum, and flies off to a considerable distance.

EXPERIMENT CCIII.

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

about one inch from each other. When the vacuum is good, a single uniform ray, of a purple colour, passes from one ball to the other; but in proportion as the air is admitted, the ray acquires a quivering motion, which indicates that a resistance to its motion then begins, and this interruption is followed by a division of the ray or stream; the ray now acquires a more vivid light; and, lastly, it becomes the common spark, which is emitted with greater or less facility, in proportion to the power of the machine, and the resistance of the air.

E X P E R I M E N T C C I V .

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

The flexuous motions of the electric fluid in an exhausted receiver may, in some degree, be produced at pleasure. By wetting the outside of the receiver, the fire will follow the direction of the wetted line, as the resistance is now lessened on one side; and the fire can adhere and accumulate itself on the inside of the receiver, because, by means of the dampness, it can expel a portion from the outside.

This experiment may be exhibited very pleasingly, by making a Torricellian vacuum in a glass tube about three feet long, and then sealed hermetically. Hold one end of this tube in the hand, and apply the other to the conductor, and immediately the whole tube will be illuminated from end to end, and will continue so for a considerable time after it is removed from the conductor, flashing at intervals for many hours.

EXPERIMENT CCV.

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

X

metal

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 CCVI.

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 the receiver. Upon making the discharge, the light is seen to return in a close body.

EXPERIMENT CCVII.

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 basin
of

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 CCVIII.

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 *cd* proceed into the tube. Fill this tube with quicksilver, and then, by sending up a large bubble of air, and repeatedly inverting the tube, free the quicksilver and iron ball from air, according to the ordinary mode of filling barometers; then place a small drop of æther on the quicksilver, and put the finger on

the end of the glass tube, invert the tube, and then insert the end *f* in a basin of quicksilver, taking care not to remove the finger from the end of the tube, till the end is immersed 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. I am indebted for this valuable experiment to Mr. Morgan, of the Equitable Assurance Office.

EXPERIMENT CCIX.

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

that when the receiver was exhausted, the spark passed from the cap to the plate of the pump through the receiver, illuminating its whole cavity; that the vacuum became a better conductor of electricity in proportion as it was more perfect, and that the electric light was more equally diffused, but it was by no means faint when the receiver was exhausted to the utmost. The light changed according as the receiver was more or less exhausted. The appearances were as follows.

DEGREE OF RAREFACTION, AS SHEWN BY THE GAGE.	APPEARANCES OF THEELEC- TRIC LIGHT WITHIN THE RECEIVER.
Air rarified 40 times.	{ Light in large, long, but divided streams. { Fine diffused light of a white colour. { Beautiful diffused light inclining to red or purple, and filling the whole receiver. { A diffused light fil- led equally the re- ceiver; it had hardly any reddish hue *.
70	
80	
100 400	
When the gage shew- ed the utmost de- gree of exhaustion.	

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

See also EXPERIMENT CXII, CXIII, CXXI, CXXII, of this Essay, for further observations on the appearance of the electric light IN VACUO.

C H A P. XV.

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 ; to learn to make the electrical machine act well, and then apply it for a few weeks to some of those disorders in which it has been administered with the greatest success ; and there is no doubt but they would soon be convinced that it deserves a distinguished rank in medicine, which is the offspring of philosophy,

The science of medicine and its practitioners have been reproached with the instability and fluctuations of practice ; at one time cold as the ice at Zembla, at another hot as the Torrid Zone ; that they are led by fashion, and influenced by prejudice. On this ground it has been predicted, that however great the benefits which may be derived from electricity, it would still only last for the day of fashion, and then be consigned to oblivion. I must confess, that I cannot be of this opinion, nor easily led to think a set of men whose judgment has been matured by learning and experience, will ever neglect an agent, which probably forms the 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. To give one instance, among many, it has been shewn, that the rain that descends in a storm is strongly impregnated with electricity, and thus brings down what the heated vapours carried up into the air, till the deficiency of the earth is supplied from the superfluity of the heavens. A variety of other causes concur to vary continually the equilibrium of this fluid; as the perpetual intestine and oscillatory motion, which contributes so much towards carrying on the operations of nature. Further, if a particular portion of this fluid is distributed to every substance, then every alteration of its capacity, which is continually changing by heat or cold, must move or operate on it.

As heat, or fire in action is the first mover in the animal machine, and the chief active principle during its existence, and as electricity exhibits so many 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 ascer-

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tains 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 chickens 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
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are arrested by the earth; an idea which is strongly corroborated by the observations made on atmospherical electricity, and by the deductions which have been made from the relative affinities of fire, light and heat.

The agency of this fluid, and its existence in animated nature, 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 its size, is more liberally supplied with nerves than the Torpedo: nor yet do these nerves of the electric organs seem necessary for any sensation that can belong to them: and with respect to action, Mr. Hunter observes, that there is no part of any animal, however strong and constant its action may be, which enjoys so large a portion
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of them. If then it be probable, that these nerves are unnecessary for the purpose either of sensation or action, may we not conclude, that they are subservient to the formation, collection, and management of the electric fluid? especially, as it appears from Mr. Walsh's experiments, that the will of the animal commands the electric powers of its organs. If these reflections are just, we may with some probability foretell, that no discovery of consequence will ever be made by future physiologists concerning the nature of the nervous fluid, without acknowledging the lights they have borrowed from the experiments of Mr. Walsh upon the living Torpedo, and the dissection of the dead animal by Mr. Hunter*.

A variety of curious facts clearly evince, that the electric fire is essentially connected with the human frame, and is continually exerting its influence upon it. Add to this the ease with which the natural equilibrium is destroyed, and we may readily conceive, that any alteration in the quantity or intensity of action of this powerful fluid will produce corresponding changes in the habit or health of the body: the following is a remarkable instance of the agen-

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

cy of the fluid in the human frame, and of the ease with which it is put in action. Mr. Brydone mentions a lady, who, on combing her hair in frosty weather in the dark, had sometimes observed sparks of fire to issue from it; this made him think of attempting to collect the electrical fire from hair alone, without the assistance of any other electrical apparatus. To this end, he desired a young lady to stand on wax, and comb her sister's hair, who was sitting in a chair before her; soon after she had begun to comb, the young lady on the wax was 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 ma-

ny 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, its activity is lessened, and what is collected is soon dissipated; then our spirits are more languid, and our sensibility is less acute. And in the fierce wind at Naples, when the air seems totally deprived of it, the whole system is unstrung, and the nerves seem to lose both their tension and elasticity, till the north-west wind awakens the activity of the animating power, which soon restores the tone, and enlivens all nature, which seemed to droop and languish in its absence: nor can this appear 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. Galabert and Professor Sauffure, when passing the Alps, were caught among thunder-clouds, and found their bodies full of electrical

electrical fire; spontaneous flashes darting from their fingers, with a crackling noise, and the sensations they felt were the same as when strongly electrified by art. It seems pretty evident, that those feelings were owing to their bodies containing too great a share of electrical fire; and it is not improbable, that many of our invalids owe their feelings to the opposite cause.

The perpetual electricity of the atmosphere is no longer a problem: the existence and continual agency of it in that mass of air which surrounds our globe has been ascertained by numerous clear and decisive experiments, and it seems by no means improper to infer, that this fluid cannot exist in the atmosphere without exerting a certain influence on all the beings contained in it, and principally on organized bodies, among which man holds the highest rank.

E X P E R I M E N T C C X .

Pass the charge of a large jar, or battery, from the head to the back of a mouse; this, if the shock is sufficiently strong, will kill the animal. After its death, make the discharge in the same manner, and the fluid will pass visibly

sibly over the body, and not through it; evincing, that the power or medium which transmitted the shock through the animal, is lost with its life. This experiment is taken from Mr. Cavallo's treatise on medical electricity. Its importance is self-evident, and it certainly merits a further investigation, by those who are acquainted with the animal œconomy, as well as electricity.

The following experiment shews, that the electric fluid passes through that series of muscles which form the shortest passage for it, and whose conducting power, or electric capacity, is most favourable to it.

EXPERIMENT CXXI.

Let A grasp a Leyden phial with his right hand, and touch, with a brass rod held in his left hand, the naked right foot of B; let the left foot of B communicate by a brass rod with the right foot of C; let D with his right hand hold the left ear of C, and touch the knob of the bottle with his left hand: A will feel the shock in the muscles of the right hand and arm, of the thorax, and of the left hand and arm; B will feel the commotion in the muscles of his right foot, right leg and thigh, and those
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which are connected with the left thigh, leg, and foot, while C will perceive it in that series which goes from the leg to the ear by which he communicates with D. The action of the fluid on the human body in the shock, is the same when it passes through similar parts with the same density. Its action is more extensive when the fire is densest, and therefore most intense when it meets with any resistance.

Assisted by a surgeon, Beccaria made several experiments upon the effects produced by electricity on the muscles in the left leg of a cock. The muscles were strongly contracted when a shock was passed through them, and the contraction was always accompanied by a sudden and proportional swelling of the muscles, excepting at the part where the membrane is inserted, which separates one muscle from another, which was always depressed. The membrane which invested that part of the muscle through which the fluid passed, became dry and wrinkled, and a vapour arose from that part; when one muscle was contracted, a general contraction took place in those that were contiguous to it, and they were a little convulsed after the shock.

In another instance, where the muscle was relaxed and parted from the thigh, on passing

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the shock through it the muscle contracted itself, and was drawn back into its natural place, and could not be again displaced but by force; a circumstance which strongly manifests the power of electricity to give tone to a flaccid fibre. Indeed, when we consider, says a very sensible writer, that the muscles have been brought into action by the electric fire; that it has rendered palsied limbs plump, and restored a power of action and motion to many, whose palsies did not arise from the spinal marrow: is it not a convincing proof, that the vital fire is the cause of muscular motion, and that this is the same with that which is collected by the electrical machine*?

As the science of medicine knows of no specific, so we are not to suppose, that electricity will triumph over every disorder to which it is applied. Its success will be more or less extensive, according to the disposition of the subject, and the talents of those who direct it; it cannot therefore appear surprising, that many disorders have been refractory to its powers, and others have only yielded in a small degree;

* Dr. Cullen says, that Electricity, when properly applied, is one of the most powerful stimulants that can be used to act upon the nervous system of animals.

or, that the progress of the cure has often been stopped by the impatience, or prejudice, of the diseased: but at the same time, it must be acknowledged, that even in its infancy, when it had to combat against fear, prejudice, and interest, its success was truly great: we have surely then the highest reason to expect a considerable increase of success, now that it is cultivated and promoted by professional men of the first merit.

E X P E R I M E N T C C X I I .

This experiment shews, 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, of 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.

E X P E R I M E N T C C X I I I .

Insulate a sensible 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.

Mr. Morgan, in his examination of Dr. Crawford's Theory of Heat, was the first person who proved that the mercury in the thermometer might be raised by electricity.

The public have long expected that some system of the application of Medical Electricity would be produced; but the gentlemen into whose hands the chief practice has fallen, know the fallacy of systems too well to hazard any which is not built on experience.

In a short course of lectures which were read on this subject last winter by Mr. Birch, something like a system was thrown out for the consideration of future electricians. The application of electricity to medicine was divided into three forms; namely, the fluid, the spark or friction, and the shock. The first mode he considered to act as a Sedative, the second he ranked under the title of a Stimulant, and the last as a Deobstruent. As the distinctions were

the result of many experiments and much observation, they may safely be adopted for the present. That gentleman being now engaged in the practice of a great hospital, where his electrical experiments have already gained some reputation, we may hope the science will be more universally diffused, and being taught under the cautious eye of public scrutiny, we may trust its merits will soon give it an established rank in the art of healing.

From hence we may perceive that 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,

dicine, for it applies directly to the seat of the disease, with a power and rapidity unknown in physic, and perfectly manageable at discretion; and, as it is a remedy which applies to the understanding as well as to the feelings, I should think it better worth the attention and contemplation of men of liberal education, than the compounding a medicine, in which they place little faith, or applying a plaister, in which they have none at all.

The success of electricity, in relieving the sufferings of mankind, has been considerably promoted, and its operations rendered more rapid, sensible, and efficacious by applying it in different manners and quantities to the human frame. The modes formerly used were the shock, spark, and sometimes, though very seldom, simple electrification. These modes are now varied, and their number augmented. The stream of the electric fluid may, without a shock, be made to pass through any part of the body; it may also be thrown upon, or extracted from any part, and its action in each case varied, by causing the fluid to pass through materials which resist its passage in different degrees; it may be applied to the naked integuments, or to the skin covered with different resisting substances; and its power may be rarified or condensed, confin-

ed 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. (The machine represented in the plate which faces the title-page of this Essay, is the kind which Mr. Birch recommended to medical practitioners in his lectures.)

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 its end. The wire of one is bent, for the more conveniently throwing the electric fluid on the eye, &c. The balls may be unscrewed from the wires, and the wooden point B screwed in its place, or the pointed end of the brass wire may be used. The directors should always be held by that extremity of the glass handle which is farthest from the brass, and care should be taken that the heat of the hand does not make them moist.

L and M, fig. 84, represent glass tubes, through which small wires are made to pass, to convey the fluid directly to the ear or throat.

Fig. 88 represents another glass tube, of a larger size, the end of which is capillary; a small quantity of rose water, or any other fluid, is to be poured into this tube; then connect it with the prime conductor by a wire; turn the cylinder, and a subdivided, gentle and refreshing stream of this fluid may be thrown on the patient.

Fig. 86 represents the electric forceps: some gentlemen think it is a very convenient instrument for communicating a shock. Its use is evident from an inspection of the figure.

Fig. 85 is the medical bottle, furnished with
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an electrometer, to limit the force of the shock, and enable the operator to give a successive number of them of the same force. C is a bent piece of glass, on the upper part of which is cemented a brass socket D, furnished with a spring tube E; the wire F moves in this tube, so that the ball G may be set at a convenient distance from the ball H. The end I of the bent piece of glass is also furnished with a spring tube, which slides upon the wire K, communicating with the inside of the bottle.

To use this bottle, place the ball H in contact with the conductor, or connect them together by a wire, and then charge it in the usual manner. Now, if a wire proceeds from the ball L to the outside coating, the bottle will be discharged whenever the fluid has acquired sufficient force to pass through the space of air between the two balls; consequently the shock is stronger in proportion as the distance between the two balls is increased.

It is obvious, that when the electrometer is thus connected, it acts in the same manner as a common discharging rod, and forms the communication between the outside and the inside of the bottle; with this difference only, that the distance of the end which is to communicate with the inside may be limited and regulated.

It has been found more convenient, to separate the electrometer from the bottle, and apply it to the conductor: see in the frontispiece to this Essay, where *a, b*, represents the electrometer, *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 its 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 its shape and some other circumstances in giving small shocks.

The handles of the directors should be carefully dried, as also the bent piece of glass C, and those parts of the 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.

Fig. 87 represents an universal discharger upon

upon a large scale, with a patient fitting between the two pillars, one ball resting at A, the other being placed at B. The convenience of this apparatus is obvious, from an inspection of the figure; for as the joints have both an horizontal and vertical motion, and the wires pass through two spring sockets, they may therefore be placed in any direction, and the balls fixed in any required situation. Hence, 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, that a person may, by means of the two joints of this simple apparatus, 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, by means of this universal discharger. 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 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
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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 tumors, 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 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 by 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

cular propriety to spasm, pleurisy and some stages of the palsy, and in every case answers the end of blistering where the discharge is not wanted, being the most safe and powerful stimulant we know.

4. BY TAKING STRONG SPARKS FROM THE PATIENT.

Here, as in every other case, the operator may connect the ball of the director with the positive or negative conductor, or he may connect the patient with either of these and the ball with the ground; now it is clear from what has been already laid down, that if the director be connected with the positive conductor, the fluid is thrown upon the patient, if with the cushion, the fluid is extracted from him. Let the patient be insulated, and the action is in some measure reversed; if he is joined to the negative conductor or cushion, he will receive a spark from a person standing on the floor, but if he communicates with the positive conductor he will give the spark to the person on the ground.

5. BY CAUSING A CURRENT OF THE ELECTRIC FLUID TO PASS FROM ONE PART OF THE BODY, AND THUS CONFINING AND CONCENTRATING ITS OPERATION WITHOUT COMMUNICATING THE SHOCK.

Place the patient in an insulated chair, and touch one part of the body with a director, joined to a positive conductor; then with a brass ball communicating with the ground, touch another part, and when the machine is in action the fluid will pass through the required part, from the conductor to the ball; the force of the stream will be different according to the strength of the machine, &c. Or connect one director with the cushion and the other with the positive conductor, and apply these to the part through which the fluid is to pass, and when the machine is in action the electricity will pass from one ball to the other. It is not necessary to insulate the patient in this case.

6. BY THE SHOCK.

Which may be given to any part of the human body, by introducing that part of the body into the circuit which is made between the outside and
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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 circuits he desires: when this happens, which may be known by the chattering noise of the spark in passing to the electrometer, the resistance formed to the discharge is so great that the fluid cannot force its way through the circuit; to remedy this, and lessen the resistance, pass two

metallic pins through the clothing, 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, and leaving the shorter one which is connected with the tube in its place, the directors to be connected and used as before. In lessening this vibratory shock the electrometer may be drawn to a much greater distance; for the rapidity with which the charge of the 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 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, Pl. V. will be discharged whenever the ball *b* is brought in contact with the patient, so that by bringing it down with rapidity any number of sparks may be procured in a minute. Or connect the insulated patient with the top or inside of a large charged jar, and then this apparatus used in the foregoing manner will discharge, from the large jar at each spark, its own contents, and by repetition discharge the whole jar; thus a number of shocks may be given without continually turning the machine or employing an assistant.

9. BY PASSING THE WHOLE FLUID CONTAINED IN THE LEYDEN 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 condensed

condensed in the phial will be thrown on the part in a dense flow 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 flow 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 cafes, the electric friction is generally used. If the pains are local, small shocks may be given. To relieve the tooth-ach, very small shocks may be passed through the tooth; or, cover the part affected with flannel, and rub it with a director, communicating with the machine.

In inflammations, and other disorders of the eyes, the fluid should be thrown from a wooden point: the sensation here produced is that of a gentle cooling wind; but, at the same time, it generates a genial warmth in the part affected.

In palsies, the electric friction and small shocks are administered. Streams of the fluid should always be made to pass through the affected part.

The only treatise we have yet had from the Faculty, on the subject of Medical Electricity, is a pamphlet intitled, "Considerations on the Efficacy of Electricity in removing Female Obstructions," by Mr. Birch; to whom I am indebted for a variety of important observations and practical remarks on the different branches of electricity; and if its merits were to be confined to this disease alone, (in which it may be reckoned a specific) it would be intitled to the

attention of practitioners ; but we have reason to expect much more from it, since the prejudices of the Faculty seem removed, and the practice is becoming more general every day.

C H A P.

C H A P. XVI.

MISCELLANEOUS EXPERIMENTS AND OBSERVATIONS.

THE dispute concerning the preferable utility of pointed or knobbed conductors, for securing buildings from lightening, occasioned the setting up a more magnificent apparatus than had ever appeared before. An immense conductor was constructed, at the expence of the Board of Ordnance, and suspended in the Pantheon, under the direction of Mr. Wilson. It consisted of a great number of drums, covered with tin-foil, which formed a cylinder of about 155 feet in length, and more than 16 inches in diameter; and to this vast conductor was occasionally added 4800 yards of wire. The electric blast from this machine fired gun-powder in the most unfavourable circumstances, namely, when it was drawn off by a sharp point. The method of doing it was as follows: upon a staff of baked wood a stem of brass was fixed, which terminated in an iron point at the top; this point was put into the end of a small tube of India-paper, made somewhat in the form of a cartridge, about an inch and a quarter long, and two tenths of an inch in diameter, when the cartridge was filled

with common gun-powder unbruised; a wire, communicating with the earth, was then fastened to the bottom of the brass stem. The charge of the great cylinder being continually kept up by the motion of the wheel, the top of the cartridge was brought very near the drums, so that it frequently touched the tin-foil with which they were covered. In this situation, a small, faint, luminous stream was frequently observed between the top of the cartridge and the metal. Sometimes this stream would set fire to the gun-powder the moment it was applied; at others, it would require half a minute or more before it took effect. This difference in time was supposed to be owing to some small degree of moisture in the powder, or the paper.

Gun-powder may also be fired by a stream from a large charged Leyden jar, in the following manner:

EXPERIMENT CXXIV.

Fix a small cartridge on a metallic point, which is fitted to a wooden or glass handle; make a communication from the wire to the ground, then present the cartridge to the knob of the phial, and the gun-powder will be fired by the passage of the electric stream through
the

the cartridge. Tinder, or touch-wood, placed in a metal cup, may be lighted by passing the stream from the inside of the jar through them, as in the foregoing experiment, without completing the circuit.

As it therefore appears, that the electric fluid, when it moves through bodies, either with great rapidity, or in great quantities, will set them on fire, it is scarce disputable, that this fluid is the same with the element of fire.

EXPERIMENT CCXV.

To fire the small electrical cannon, charge it with gun-powder in the usual manner, then fill the ivory touch-hole with gun-powder, ram it well down, and push the brass pin down, so that the end of it may be near the bottom of the hole; make a communication between the outside of a large charged jar or battery and the body of the cannon, by placing one end of the discharging rod on the pin which passes down the touch-hole, and bring the other end to the knob of the jar, and the discharge will fire the powder.

EXPERIMENT CCXVI.

Fig. 89 is a perspective view of the powder-house; the side of the roof next the eye being omitted

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

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

EXPERIMENT CCXVII.

Fix the ladle I, fig. 33, into a hole at the end of the conductor. Place a broad piece of camphor in the ladle, set the upper surface of the camphor on fire, let it burn some time, then extinguish it, and put the machine in action; the upper surface of the camphor will throw out a variety of small shoots, and have the appearance of an imperfect vegetation, which is soon dispersed in the air if the machine is continued in action, but will last some time if the electrization is stopped as soon as the shooting of the camphor has taken place,

EXPERIMENT CCXVIII.

Wrap some loose cotton, which has been previously rolled in fine powder of yellow resin, round one of the balls of a discharging rod, and hold the other end to the outer coating of a charged jar; then bring the knob with the resin towards the ball of the jar, and the explosion will fire the resin, and this will communicate the flame to the cotton.

Fig. 91 represents the inflammable air lamp, invented by Mr. Volta. A is a glass globe to contain

contain the inflammable air, B a glass basin, 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 basin B into the ball A.

To use this instrument, after having filled the reservoir A with pure inflammable air, and the basin with water, turn the cocks D and S, and the water which falls from the basin 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

To fill the reservoir Aa 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 economical purposes, as the smallest spark from an electrophorus, or a small bottle, is sufficient to fire the air.

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

The following experiment was made by Mr. Kinnerly with his electrical thermometer, which is described in page 42 of this Essay.

EXPERIMENT CCXIX.

Having put some tinged water into the large tube, he placed the two wires within the tube in contact, and passed a large charge of electricity from above thirty square feet of coated glass, which produced no rarefaction in the air, and shewed that the wires were not heated by the fire passing through them. When the wires were about two inches asunder, the charge of a three-pint bottle, darting from one to the other, rarified the air very evidently. The charge of a jar, which contained about five gallons and a half, darting from wire to wire, occasioned a very considerable expansion in the air; and the charge of a battery of thirty square feet of coated glass would raise the water in the small tube quite to the top: upon the coalescing of the air, the column of water instantly subsided, till it was in equilibrio with the rarefied air; then gradually descending as the air cooled, settled where it stood before. By carefully observing at what height the descending water first stopped, the degree of rarefaction might be easily discovered.

EXPERIMENT CCXX.

Take a glass tube, about four inches long, one quarter of an inch in diameter, and open at both ends; moisten the inside of the tube with oil of tartar per deliquium, then fix two pieces of cork into the ends of the tube, and pass a wire through each cork, so that the ends of the wires which are within the tube may be about three quarters of an inch asunder. Connect one wire with the outside coating of a large jar, and form a communication from the other to the ball of the jar, so as to pass the discharge through the tube; repeat this several times and the oil of tartar will very often give manifest signs of crystallization*.

EXPERIMENT CCXXI.

Charge a Leyden phial, (the top of which is cemented into the bottle) place it upon an insulated stand, and then take hold of it by the ball, and present the coated surface towards the condensing ball of a prime conductor while the

* Cavallo on Medical Electricity, p. 117.

cylinder is charging, and a large brush and spark will pass between the coating of the bottle and the ball of the conductor, from four to twelve inches and upwards in length.

EXPERIMENT CCXXII.

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 CCXXIII.

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

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 distance above the phosphorus, for if it passes through it, the whole of the powder in the track of the fluid will be torn off.

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

As the experiments on phosphorus are in themselves exceedingly curious, and appear to me to be intimately connected with the nature of electricity, I hope I shall not be thought to have deviated too far from the subject of this essay by introducing some experiments of Mr. Wilson on this subject; the more so, as the producing the prismatic colours is by no means difficult, as little more is required than a few oyster-shells, and a good fire of any kind. For, if those shells are thrown carelessly into the middle of the fire, and continued there for a proper time, (which may be from 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 ex-

hibit lively prismatic colours, after they are removed from the sun into the dark suddenly, and the eyes have been previously prepared a little to receive them. Mr. Wilson excited also the light of these shells with electricity in the following manner.

EXPERIMENT CCXXIV.

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-

colour-making parts. These colours continued visible several minutes, and when they ceased to appear, a white purplish light occupied their places, which lasted for a considerable time. And notwithstanding this experiment was repeated with the same and other shells, the colours continued in their respective places, and nearly of the same degree of brilliancy; excepting, that in or near those parts where the explosion took place a few scales were driven off.

EXPERIMENT CCXXV.

Which proves, that bodies of the same nature, but of different volumes and different masses, are charged with electrical matter only in proportion to their surface, without any influence or concurrence of their masses in this case.

The following experiment, which we shall give in Mr. Achard's own words, seems to decide this question, on which philosophers have entertained very different opinions.

I electrified (says he) a cylindrical, hollow brass conductor, seven inches long, and one and a half in diameter: when it had acquired forty degrees of electricity, I drew from it a

spark, with a conductor of hollow brass, of seven inches long, and one and a half in diameter, which weighed eight ounces, and was carefully insulated. The first conductor lost fifteen degrees of its electricity. I repeated the same experiment, when the conductor had thirty degrees of electricity, and then it lost ten degrees. Finally, when the conductor had twenty degrees of electricity, it lost only seven by its instantaneous contact with the same cylinder. After having filled this cylinder with lead, which produced an addition of five pounds to its weight, and consequently to its mass, I repeated the same experiments, and obtained from them the very same results.

This is followed by other experiments, which are a farther confirmation of Mr. Achard's opinion.

These experiments shew, 1st. That bodies of an equal surface, but different in mass, when they are placed in the same circumstances, are charged with an equal quantity of electrical matter; and 2dly, That bodies equal in mass, but different in extent of surface, when they are placed in similar circumstances, are charged with an unequal quantity of electrical matter, and that the body, whose surface is larger, receives more than that whose surface is less.

Therefore,

Therefore, it is in proportion to their surfaces, and not to their mass, that bodies are charged with a greater or less quantity of the electrical fluid.

Before these experiments were made it had been observed, that the extreme subtilty, and, in most cases, invisibility of the electric fluid, render all reasoning about its motion precarious. It is however incredible, that this fluid should pass through the very substance of metallic bodies, and not be retarded by their solid particles. In those cases, where the solid parts of metals are evidently penetrated, i. e. when wires are exploded, there is a manifest resistance, for the parts of the wire are scattered about with violence in all directions.

The like happened in Dr. Priestley's circles, made on smooth pieces of metal. Part of the metal was also dispersed and thrown off, for the circular spots were composed of little cavities. If therefore the fluid was dispersed throughout the substance, and not over the surface of the metal, it is plain, that a wire, whose diameter is equal to one of those circular spots, ought also to have been destroyed by an explosion of equal strength sent through it; whereas, a wire, whose diameter is equal to one of those spots, would without injury conduct a shock much greater

than any battery hitherto constructed could give. It is most probable, therefore, that though violent flashes of electricity, which act also as fire, will enter into the substance of metals and consume them, yet it immediately disperses itself over their surface, without entering their substance any more, till being forced to collect itself into a narrow compass, it again acts as fire.

In many cases the electric fluid will be conducted very well by metals reduced to a mere surface. A piece of white paper will not conduct a shock, without being torn to pieces, as it is an electric substance; but a line drawn on it with a black lead pencil will safely convey the charge of several jars. It is impossible we can think, that the fire here passes through the SUBSTANCE of the black lead stroke; it must run over its surface; and if we consider some of the properties of metals, we shall find that there is great reason to suppose that their conducting power lies at their surface.

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

of the wire within the tube is bent at right angles to the rest of the wire.

EXPERIMENT CCXXVI.

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

This experiment appears more beautiful when it is made in the dark. After the first hole is made, turn the end of the wire round towards another part of the glass tube, and a second hole may be made in the same manner. This experiment was communicated to me by the Rev. Mr. Morgan, of Norwich, who has carried it much farther, by filling small bottles with cement, and then passing the shock in a similar mode through them. The perforation

may be made with water in the tube instead of oil.

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

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

Analogous to this experiment of Mr. Morgan are some observations of Dr. Priestley, who constantly found, that whenever he had covered the fractured place of a jar with any kind of cement or varnish, it always broke at the place where the cement terminated; there the glass was perforated, and a new fracture was made, which had no communication with the former. The jar always broke at the first charge, generally before it had received half its charge. Struck with this phenomenon, the Doctor proceeded to try the experiment on a
jar

jar which was not broken, and whose strength he had previously ascertained by repeated discharges: he took off a little of the outside coating, and put on the glass a patch of cement, about an inch in diameter, then drawing the coating over it, he charged the jar, but before it had received half its charge, it burst by a spontaneous explosion, not indeed at the termination, but at the middle of the patch of cement, where the glass was thinnest. He covered another entirely with cement, and it broke near the bottom, where the glass is generally thickest. A jar that was covered entirely both inside and outside with cement, and then coated with tin-foil, burst at the very first attempt to charge it.

EXPERIMENT CCXXVII,

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

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.

E X P E R I M E N T C C X X V I I I .

Put a quantity of brass dust into a coated jar, and when it is charged invert it, and throw some of the dust out, which will be spread in an equable and uniform manner on any flat surface, and fall just like rain or snow. May it not be questioned, says an ingenious writer, whether water, falling from the highest region of the clouded atmosphere, would not meet the earth in much larger drops, or in cataracts, if the coalescing power of the drops was not counteracted by their electric atmospheres?

EXPERIMENT CCXXIX.

Place a piece of smoking wax-taper on the prime conductor; turn the cylinder; the volume of smoke will become more contracted, and its motion upward accelerated. Take off the electricity of the conductor, and suspend a pair of pith balls over it, and about five feet distance from it, turn the machine, and in a few seconds the balls will open half an inch; remove the taper, and the balls will not separate.

This experiment, therefore, clearly evinces, that smoke is a conductor of electricity.

EXPERIMENT CCXXX.

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

E X P E R I M E N T C C X X X I .

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.

I made several of these luminous discharging rods, many years since, in order to shew, that the electric fluid issues from the negative and positive coating of each discharge, agreeable to the idea conveyed by Mr. Atwood's experiments; see Exp. cxx, cxxi, cxxii, of this Essay. But I soon found, that the circuit of a discharging rod was not sufficiently extensive for the purpose.

E X P E R I M E N T C C X X X I I .

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

furnished with a ball at each end, and nicely balanced, is placed on this point: place the middle of this wire under a ball proceeding from the conductor, so that it may receive a continued spark from the ball, then give the wire a rotative motion, and the balls in revolving will give a spark to each ball of the spiral tube, which will be communicated from thence to the board; forming, from the brilliancy of the light and its rapid motion, a very pleasing experiment.

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

EXPERIMENT CCXXXIII.

Suspend a light cork ball, which is covered over with tin-foil or gold-leaf, by a pretty long silk thread, so as just to touch the knob of a charged jar placed on a table; it will be first attracted and then repelled to some distance, where, after a few vibrations, it will remain at rest. If a lighted candle is now placed at some distance behind it, so that the flame of the candle may be nearly as high as the knob
of

of the phial, the cork will instantly be agitated, and, after some irregular motions, will describe a curve round the knob of the phial, and this it will continue to do for some time.

Fig. 96 and 97 represent an electrometer, nearly similar to that contrived by Mr. Brooke. The two instruments are sometimes combined in one, or used separately, as in these figures. The arms F H f k, fig. 97, when in use, are to be placed as much as possible out of the atmosphere of a jar, battery, prime conductor, &c. The arm F H and the ball K are made of copper, and as light as possible. The divisions on the arm F H are each of them exactly a grain. They are ascertained at first by placing grain weights on a brass ball which is within the ball L, (this ball is an exact counterbalance to the arm F H and the ball K when the small slide r is at the first division) and then removing the slide r till it, together with the ball K, counterbalances the ball L and the weight laid on it.

A, fig. 69, is a dial-plate, divided into 90 equal parts. The index of this plate is carried once round, when the arm B C has moved through 90 degrees, or a quarter of a circle. That motion is given to the index by the repulsive

five

five power of the charge acting between the ball D and the ball B*.

The arm BC being repelled, shews when the charge is increasing, and the arm FH 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 BC 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,

* Philosophical Transactions, Vol. 82, p. 384.

will melt a wire of such a size, or kill such an animal, &c.

Mr. Brooke 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 FH, when the slide is removed to them.

Mr. Achard has shewn clearly, that if the scale of an electrometer is divided into equal parts (degrees for example) the angle at which the index is held suspended by the electric repulsion will not be a true measure of the repulsive force; to estimate which truly, he demonstrates that the arc of the electrometer should be divided according to a scale of arcs, the tangents of which are in arithmetical progression.

OBSERVATIONS AND EXPERIMENTS MADE BY
DR. PRIESTLEY ON THE EFFECTS OF ELECTRICITY ON DIFFERENT ELASTIC FLUIDS.

EXPERIMENT CCXXXIV,

To change the blue colour of liquors, tinged with vegetable juices, 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.

B b

When

When Dr. Priestley made this experiment, he perceived, that after the electric spark had been taken, between the wire *b* and the liquor at *a*, about a minute, the upper part of it began to look red; in two minutes it was manifestly so, and the red part did not readily mix with the liquor. If the tube was inclined when the sparks were taken, the redness extended twice as far on the lower side as on the upper. In proportion as the liquor became red, it advanced nearer to the wire, so that the air in which the sparks were taken was diminished; the diameter amounted to about one fifth of the whole space; after which, a continuance of the electrification produced no sensible effect.

To determine, whether the cause of the change of colour was in the air, or in the electric matter, Dr. Priestley expanded the air in the tube, by means of an air-pump, till it expelled all the liquor, and admitted fresh blue liquor in its place; but after this, electricity produced no sensible effect on the air or on the liquor; so that it was clear, that the electric matter had decomposed the air, and made it deposit something of an acid nature. The result was the same with wires of different metals. It was also the same when, by means of a bent tube, the spark was made to pass from the liquor

liquor in one leg, to the liquor in the other. The air thus diminished was in the highest degree noxious.

In passing the electric spark through different elastic fluids it appears of different colours. In fixed air, the spark is very white; in inflammable and alkaline air, it appears of a purple or red colour. From hence we may infer, that the conducting power of these airs is different, and that fixed air is a more perfect non-conductor than inflammable air.

The spark was not visible in air from a caustic alkali, made by Mr. Lane, nor in air from spirit of salt; so that they seem to be more perfect conductors of electricity than water, or other fluid substances.

The electric spark, taken in any kind of oil, produces inflammable air. Dr. Priestley tried it with ether, oil of olives, oil of turpentine, and essential oil of mint, taking the electric spark in them without any air to begin with; inflammable air was produced in them all.

Dr. Priestley found, that on taking a small electric explosion for an hour, in the space of an inch of fixed air, confined in a glass tube one tenth of an inch diameter, when water was admitted to it, only one fourth of the air was imbibed. Probably the whole would have

been rendered immiscible in water, if the electrical operation had been continued a sufficient time.

The electric spark, when taken in alkaline air, appears of a red colour; the electric explosions, which pass through this air, increase its bulk; so that, by making about 200 explosions in a quantity of it, the original quantity will be sometimes increased one fourth. If water is admitted to this air, it will absorb the original quantity, and leave about as much elastic fluid as was generated by the electricity, and this elastic fluid is a strong inflammable air.

Dr. Priestley found, that 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.

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 in it, was, to all appearance, as black as the first; so that the air seems to be all convertible into this black substance.

Thinking this diminution of the vitriolic acid air might arise from its absorption by the cement, with which the glass tubes employed in the last experiment were closed, he repeated it with the air from quicksilver, in a glass syphon confined by quicksilver, and the result was the same.

That this matter comes from the vitriolic acid air only; and not from any combination of the electric matter with it, will appear from the following experiment:

He took the simple electric spark from a conductor of a moderate size, for the space of five minutes without interruption, in a quantity of vitriolic acid air, without producing any change in the inside of the glass; when immediately

after, making in it only two explosions of a common jar, each of which might be produced in less than a quarter of a minute with the same machine in the same state, the whole of the inside of the tube was compleatly covered with the black matter. Now had the electric matter formed any union with the air, and this black matter had been the result of that combination, all the difference that would have arisen from the simple spark or the explosion, could only have been a more gradual, or a more sudden formation of that matter.

A large phial, about an inch and a half wide, being filled with this air, the explosion of a very large jar, containing more than two feet of coated surface, had no effect upon it; from which it should seem, that in these cases, the force of the shock was not able to give the quantity of air such a concussion as was necessary to decompose any part of it.

He had generally made use of copper, but afterwards he procured this air from almost every substance from which it could be obtained; the electric explosion taken in it produced the same effect. But, as some of the experiments were attended with peculiar circumstances, he briefly mentions them, as follows.

When

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 other experiments. Water being admitted to this air, there remained a considerable residuum, which was very slightly inflammable.

Vitriolic acid air is easily procured from spirit of wine, the mixture becoming black before any air is yielded. The electric explosion taken in this air also produced the black matter.

The experiments made with ether seem to throw most light upon this subject, as this

air is as easily procured from ether as any other substance, containing phlogiston. In the air procured by ether the electric explosion tinged the glass very black, more so than in any other experiment of the kind; and, when water had absorbed what it could of this air, there was a residuum in which a candle burned with a lambent blue flame. But what was most remarkable in this experiment was, that besides the oil of vitriol becoming very black during the process, a black substance, and of a thick consistence, was formed, which swam on the surface of the acid.

It is very possible, that the analysis of this substance may be a means of throwing light upon the nature of the black matter, formed by electric explosions, in vitriolic acid air, as they seem to resemble one another very much.

The electric spark or explosion, taken in common air, confined by quicksilver in a glass tube, covers the inside of the tube with a black matter, which, when heated, appears to be pure quicksilver. This, therefore, may be the case with the black matter into which he supposed the vitriolic acid air to be converted by the same process, though the effect was much more remarkable than in the common air. The explosion

plosion 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.

EXPERIMENT CCXXXV.

This curious experiment was made by Mr. Marsham, originally with a view to melt wires with a small Leyden bottle. The effects are curious, and seem to open a new field for investigating the force and direction of the electric fluid. He fixed a small piece of wax upon the outside coating of the Leyden bottle; the head of a small needle was stuck in the wax, so as to be at right angles to the coating; opposite to the point of this needle, and at half an inch distance, another needle was fixed, by being forced through the bottom of a chip box; this was connected with the discharging rod by a wire. On discharging the bottle, the
needle

needle with the wax was driven from the coating of the bottle, and fixed into the box opposed to it. The distance between the needles was then increased to two inches and a half, which was the greatest striking distance. The head of the needle, which was fixed to the bottle, was evidently melted in two or three places. If the charge was strong, and the wax was not stuck fast to the coating of the bottle, both the wax and the needle would be driven some inches from the bottle. On placing a ball of wax on the point of each needle, and passing the discharge through them, the ball was thrown from that connected with the bottle full two feet. Repeating this again, he could not produce the same effect.

Mr. Marsham now fixed the needle, opposed to that on the bottle, with wax on a brass plate. On passing the charge through them, when the needles were half an inch distance from each other, the needle was thrown six inches from the brass plate, while the other remained in its situation. On increasing the distance, the effects were the same, till it came to one inch and a half, when neither were thrown off. In many instances, both were thrown off, leaving the wax behind them.

The needles in all these experiments passed through

through the wax, so as to touch the coating of the bottle and the brass plate; both the coating and plate were beautifully fused at each explosion.

Mr. Marsham then substituted small pieces of putty instead of wax; when on making the discharge with the points, at only three-eighths of an inch, the needle was driven from the bottle, and the putty forced up the needle. The points were then placed as near each other as was possible; when, on making the discharge, the putty of both needles was blown to pieces, and the needle thrown at a considerable distance; the brass plate was also curiously melted, and the bottle broke.

EXPERIMENT CCXXXVI.

Cut a piece of India or thin paper, into the shape of an isosceles triangle, whose sides are about two inches long, breadth two tenths of an inch; then erect a brass ball of two or three inches diameter, on a brass wire one sixth of an inch diameter, and two feet six inches long, on the prime conductor; electrify the conductor, and then bring the obtuse end of the pieces of paper within the atmosphere of the ball, and let
it

it go, and the paper will revolve round the ball and often round its own axis. This pleasing and exceeding curious experiment was communicated to me by the ingenious Mr. J. Gamble of Pembroke-Hall, Cambridge.

E X P E R I M E N T C C X X X V I I .

Electrify two pieces of swans down; one negatively, and the other positively; they will then float in the air, and may be easily driven about by bottles charged with contrary electricity; when brought near together, they will attract each other, meet with rapidity, their fibres will collapse, and they will then fall to the ground, representing in miniature what may be supposed often to happen in the higher regions of the atmosphere.

E X P E R I M E N T C C X X X V I I I .

Insulate a Leyden phial, and connect a set of electrical bells with the inside of the phial, and another set with the outside; charge the phial, and then touch the set of bells connected with the inside; these will cease ringing, and the other set will begin to ring: now touch these, and then the set connected with the inside will
ring:

ring : and so on alternately till the bottle is discharged. Thus illustrating in a pleasing manner the received theory of the Leyden phial.

A distinct apparatus is often fitted up for the performing of this experiment : or it may be shewn by means of the apparatus represented Fig. 49. Pl. III. which can easily be applied to a great variety of purposes, and is sufficient for explaining most part of the phenomena relative to the Leyden phial, besides being very convenient for several pleasing experiments.

ON THE ANALOGY BETWEEN THE PRODUCTION AND EFFECTS OF ELECTRICITY AND HEAT, AND ALSO BETWEEN THE POWER BY WHICH BODIES CONDUCT ELECTRICITY AND RECEIVE HEAT ; WITH THE DESCRIPTION OF AN INSTRUMENT TO MEASURE THE QUANTITY OF THE ELECTRICAL FLUID, WHICH BODIES OF A DIFFERENT NATURE WILL CONDUCT, WHEN PLACED IN THE SAME CIRCUMSTANCES. BY MR. ACHARD*.

The production of heat is similar to that of electricity.

Every kind of friction produces heat and

* Memoires de l'Academie de Berlin, for 1779.

electricity.

electricity. It may be objected to this, that in order to render the analogy perfect, it would be necessary that the friction of every body should produce electricity, which appears contrary to experience, as metals and other conducting substances do not become electrical, but by the contact of electric bodies, and that the immediate friction of these substances will not render them electrical.

To this it may be answered, that when an electric body is excited by friction against a non-electric, that the last, if it is insulated, gives as strong signs of electricity as those of the electric itself. This electricity is not communicated by the electric, since it is of an opposite kind: negative, if the electric is positive; and the contrary.

This observation proves, not only that the conducting bodies become electrical by friction, as well as electric bodies, but also, that to produce electricity, it is necessary that the equilibrium between the electricity of the rubbing bodies should be destroyed; if each substance is equally adapted to receive and transmit the electrical fluid, it is clear, that the equilibrium of the fluid between them cannot be destroyed; because, that at the instant one receives from the other any given quantity, it will, by its elasticity,

ticity, be again divided between them: we may therefore conclude,

1. That the electricity produced by the friction of two bodies is greater, in proportion to the increase of the difference between the conducting power of those bodies.

2. That where two bodies are equally adapted to receive and transmit the electric fluid, they give no sign of electricity; not because they cannot become electrified by friction, but because the electricity, which is disturbed by the friction, is at the same time restored, on account of the facility with which it penetrates each substance. For a reason nearly similar, electrics, when rubbed together, do not appear electrified.

It seems therefore, that we may conclude from this theory, which is founded on fact, that in all cases, and whatever is the nature of the substance, the friction always produces electricity; and when the effect is not sensible, it is only because electricity is lost as soon as produced.

That there are no substances, that are rubbed against a body, which transmit the electric fluid with greater or less difficulty, but what give signs of electricity: that metals are as electrical by themselves as glass and wax.

That

That as friction always, and in all cases, produces electricity, there is a perfect analogy between the production of heat and electricity.

THE EFFECTS WHICH ARE PRODUCED BY ELECTRICITY, ARE SIMILAR TO THOSE PRODUCED BY HEAT.

Heat dilates all bodies. The action of the electric fluid on the thermometer shews its dilating power also; and if we do not generally perceive it, it is because the force with which bodies cohere together exceeds the dilating power of electricity.

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

Electricity, as well as heat, accelerates evaporation.

Heat and electricity accelerate the motion of the blood*. Least fear, constraint, or the 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

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

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, prove that electricity, as well as heat, favour the developement of those animals. The electric fluid, in common with fire, will throw metals into fusion.

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

THERE IS AN EXACT ANALOGY BETWEEN THE FACULTY WITH WHICH BODIES CONDUCT THE ELECTRIC FLUID AND RECEIVE HEAT.

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

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

If one extremity of an iron rod is 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; though 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

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.

If we suppose two substances, one of which is electrified, but the other not, that the first has a known degree of electricity, and that the last, in touching it, deprives it of a given degree of electricity; this loss of a part of its electricity determines the faculty with which the body that touches it receives the electric fluid. Besides the figure and volume of this substance, the time the two bodies remain in contact will alter the quantity taken from the electrified substance; so that all other circumstances being the same, the property of bodies to deprive other bodies of their electricity, or, in other words, to conduct the electric fluid, is in the inverse ratio of the time necessary to make them lose an equal degree of electricity.

The instrument which is represented fig. 95 is constructed on these principles, and with it the quantity of electricity that one body loses in a given time, when touched by another, may be accurately ascertained. A B is a very fen-

fible balance; at the extremity of each arm two very light balls of copper are affixed; C F D a divided semicircle, which is fastened to the cock which supports the axis of the balance; the degrees may be pointed out by a needle, or by the arms of the balance; the cock is fixed to a brass cap, which is cemented on the glass pillar G G, which is fixed to the board Q R S T; this pillar should be at least 18 inches high. U is a Leyden bottle; to the wire Z Z, which communicates with its inside coating, three horizontal wires, V Z, X Z, and Z Y, are fixed; the ends of these wires are furnished with hollow brass balls; the bottle U is so fixed to the board, that when the beam is horizontal, the ball B touches exactly the ball X, as is represented in the figure.

KN is a metal lever, which turns upon an axis at I, so as to move freely in a vertical plane, which should coincide with the bar V X; the lever KN is supported by a wooden pillar I H, which is fixed to the board Q R S T; at the end K of the lever is a screw, to hold the substance on which the experiment is to be made; the upper end of this substance should be turned into a convex form. A thread NO is tied to the end N of the lever; at O is a small hook, on which a ball I is to be suspended.

The

The distance of the pillar *I H* from the bottle is to be so adjusted, that when the end *N* is lowered, the body *L* may touch in one point the ball *V*; the proportion between the weight of the arms of the lever, the weight *I* and the body *L*, and the length of the pillar *I H* to the thread *N O*, is to be such, that when the substance *L* the ball *V*, at the same moment the ball *P* will touch the board *Q R S T*, and be disengaged from the thread *N O*; the substance *L* will also at the same instant quit the ball *V*.

To use this instrument, connect the bottle *U* with the prime conductor by the ball *Y*, and form a communication by a wire from *Y* to the cap *G*; charge the bottle, and the ball *X* will repel the ball *B*; the angle of repulsion will be marked by the needle *E F*. Suppose this to be 20 degrees, and let *L* be brought, as before described, to touch *V*, it will absorb a quantity of electricity proportionable to its conducting power, and the ball *B* will fall in proportion to the quantity absorbed, and the difference will be seen on the semicircle. Let the difference be five degrees; repeat the experiment, only substituting some other substance in the place of the body *L*; suppose that with this substance the diminution of the angle is 8 de-

grees, then is the conducting power of these two substances in the proportion of five to eight.

Fig. 106 represents an apparatus, to set a wire on fire by the electric explosion in dephlogisticated air. I am obliged to defer the description and use of it to some future opportunity, as I have not had any time to try its success.

A N

E S S A Y

O N

M A G N E T I S M.

A D V E R T I S E M E N T.

THIS small Effay is published to illustrate and exemplify some uses of a Magnetical Apparatus, constructed in order to exhibit the general phænomena of Magnetism. It is extracted from a larger work, which is laid aside for the present, as it is probable the public will soon be favoured with a treatise on this subject by Mr. CAVALLO.

A N

E S S A Y

ON

M A G N E T I S M.

THOUGH the phænomena of the magnet have, for many ages, engaged the attention of natural philosophers, not only by their singularity and importance, but also by the obscurity in which they are involved; yet very few additions have been made to the discoveries of the first enquirers upon the subject. The powers of genius which have been hitherto employed in prosecuting this subject, have not been able to frame an hypothesis, that will account, in an easy and satisfactory manner, for all the various properties of the magnet, or
point

point out the links of the chain which connect it with the other phænomena of the universe. Though it is certain that both natural and artificial electricity will give polarity to needles, and even reverse; from whence it would appear, that there is a considerable affinity between the electric and magnetic fluid, but how it acts when producing magnetism, is entirely unknown.

It is known by the works of Plato* and Aristotle, that the antients were acquainted with the attractive and repulsive powers of the magnet; but it does not appear, that they knew of its pointing to the pole, or the use of the compass. As they were not acquainted with the true method of philosophising, and contented themselves with observation alone, their knowledge of nature was confined within very narrow limits, and did not afford any considerable ad-

* “ A power resembling that, which acts in the stone, called by Euripides the magnet. For this stone does not only attract iron rings, but impart to those rings the power of doing that very thing which itself does, enabling them to attract other rings of iron; so that sometimes may be seen a very long series of iron rings, depending as in a chain one from another. But from that stone at the head of them is derived the virtue, which operates in them all.” See Sydenham’s translation of the IO of Plato.

vantage to society. Modern philosophers, by combining experiment with observation, soon extended the boundaries of science, and discovered the polarity of the loadstone, a property which in a manner constitutes the basis of navigation, and gives being to commerce.

THE LOADSTONE, LEADING STONE, OR NATURAL MAGNET, is an iron ore or ferruginous stone, found in the bowels of the earth, generally in iron mines; of all forms and sizes, and of various colours. It is endowed with the property of attracting iron; and of both pointing itself, and also enabling a needle, touched upon it, and duly poised, to point towards the poles of the world.

Loadstones are in general very hard and brittle, and for the most part more vigorous in proportion to their degree of hardness. Considerable portions of iron may be extracted from them. Newman says, that they are almost totally soluble in spirit of nitre, and partially in the vitriolic and marine acids.

Mr. Kirwan says, "That the magnet seems to contain a small quantity of sulphur, is often contaminated with a mixture of quartz and argill; it is possible, it may contain nickell, for this, when purified to a certain degree, acquires
the

the properties of a magnet, but its constitution has not as yet been properly examined*.

Artificial magnets, which are made of steel, are now generally used in preference to the natural magnet; not only as they may be procured with greater ease, but because they are far superior to the natural magnet in strength, and communicate the magnetic virtue more powerfully, and may be varied in their form more easily, so that the natural magnet is now very little esteemed, except as a curiosity.

The power of attracting iron, &c. possessed by the loadstone, which is also communicable to iron and steel, is called **MAGNETISM**. It has been supposed that iron and the loadstone were the only two bodies which could be rendered magnetical; but it now appears that nickel, when purified from iron, becomes more instead of less magnetic, and acquires, what iron does not, the properties of a magnet †.

A rod or bar, of iron or steel, to which a permanent polarity has been communicated, is called a **MAGNET**.

The points in a magnet which seem to possess the greatest power, or in which the virtue

* Kirwan's Elements of Mineralogy, p. 271.

† Ibid. p. 369.

seems to be concentrated, are termed THE POLES OF A MAGNET.

THE MAGNETICAL MERIDIAN is a vertical circle in the heavens, which intersects the horizon in the points to which the magnetical needle, when at rest, is directed.

THE AXIS OF A MAGNET is a right line, which passes from one pole to the other.

THE EQUATOR OF A MAGNET is a line perpendicular to the axis of the magnet, and exactly between the two poles.

The distinguishing and characteristic properties of a magnet, are,

First, Its attractive and repulsive powers.

Secondly, The force by which it places itself, when suspended freely, in a certain direction towards the poles of the earth.

Thirdly, Its dip or inclination towards a point below the horizon.

Fourthly, The property which it possesses of communicating the foregoing powers to iron or steel.

A N H Y P O T H E S I S *.

Mr. Euler supposes, that the two principal causes which concur in producing the wonder-

* Lettres à une Princesse d'Allemagne.

ful properties of a magnet are, first, a particular structure of the internal pores of the magnets, and of magnetical bodies; and, secondly, an external agent or fluid, which acts upon and passes through these pores. This fluid he supposes to be the solar atmosphere, or that subtil matter called ether, which fills our system.

Indeed, most writers on the subject agree in supposing, that there are corpuscles of a peculiar form and energy, which continually circulate around and through a magnet; and that a vortex of the same kind circulates around and through the earth.

A magnet, besides the pores which it has in common with other bodies, has also other pores considerably smaller, destined only for the passage of the magnetic fluid. These pores are so disposed as to communicate one with the other, forming tubes or channels, by which the magnetic fluid passes from one end to the other. The pores are so formed that this fluid can only pass through them in one direction, but cannot return back the same way; similar to the veins and lymphatic vessels of the animal body, which are furnished with valves for this purpose. So that the pores of the magnet may be conceived to be formed into several narrow contiguous tubes, parallel to each other, as at

A B,

A B, fig. 99, through which the finer parts of the ether pass freely from A to B, but cannot return back on account of the resistance it meets with at *a, a, b, b*, nor overcome the resistance of the grosser ether, which occasions and continues the motion. For supposing the pole A of a magnet, filled with several mouths or open ends of similar tubes, the magnetic fluid, pressed by the grosser parts of the ether, will pass towards B with an inconceivable rapidity, which is proportionable to the elasticity of the ether itself; this matter which, till it arrives at B, is separated by the tubes from the more gross parts, then meets with it again, and has its velocity retarded, and its direction changed; the stream, reflected by the ether, with which it cannot immediately mix, is bent on both sides towards C and D, and describes, but with less velocity, the curves DE and CF *e*, and approaching by the curves *d* and *c*, falls in with the affluent matter *mm*, and again enters the magnet; and thus forms that remarkable atmosphere which is visible in the arrangement of steel filings on a piece of paper that is placed over a magnet.

A SECOND HYPOTHESIS*.

1. That the earth is a large magnet.
2. That there is a subtil fluid, called the magnetic fluid, which exists in every kind of iron, is equally attracted by all its parts, and equally diffeminated throughout its substance, unless it is forced into an inequality by a power superior to the attraction of the iron.
3. That the natural quantity of magnetic fluid contained in a piece of iron, may be put in motion so as to be more rarified in one part, and more condensed in another; but it cannot be so taken away by any known force, as to leave the whole mass in a negative state with respect to its natural quantity; neither can any additional quantity be introduced so as to put it in a positive state.
4. A piece of soft iron permits the magnetic fluid which is contained in its substance to be put in motion by a small force, so that, being placed in the direction of the magnetic meridian, it acquires immediately the properties of a magnet, its magnetic fluid being drawn or pushed from one extremity to the other, and continuing so while it remains in the same po-

* *Oeuvres de Franklin. Tom: 1. p. 277.*

sition, one of the ends becoming positively, the other negatively magnetic. This transient magnet loses its properties when it is laid in an east and west situation, the magnet returning to its original situation.

If the iron is hard as steel, it is more difficult to put the magnetic fluid in motion, it requires a stronger force than is exerted by the magnetism of the earth to move it, and when moved from one end to the other, it cannot easily return, and thus a steel bar requires a permanent magnetism.

6. A great heat opens the substance and separates the parts of the bar, and thus gives a free passage for the magnetic fluid, which destroys its magnetic properties.

7. A steel bar not magnetical, placed in the direction of the magnetic meridian and dip, and first heated and then suddenly cooled, while in this posture, acquires a permanent magnetism; for while the bar was warm, the magnetic fluid contained in it was easily forced from one end to the other, by the magnetism of the earth, and was retained there by the contraction of the bar from cold.

8. Violent concussions of the steel bar placed as in the foregoing article; so separate its parts during the vibrations, as to suffer the magnetic fluid to be

forced from its situation by the magnetism of the earth, and is retained in its altered situation by the closing of the pores when the vibration cease.

9. An electric shock dilating a needle for a moment, gives it, for the foregoing reason, a magnetic virtue.

I. THERE IS A TENDENCY IN IRON AND A MAGNET TO APPROACH EACH OTHER, AND ATTACH THEMSELVES TOGETHER, AND THAT WITH SUCH FORCE, AS OFTEN TO REQUIRE A CONSIDERABLE WEIGHT TO SEPARATE THEM.

This curious property of the magnet was that by which it was first discovered, and by which it engaged the attention of the curious. Every substance which contains iron is more or less attracted by the magnet, with one exception, as Henckel, Gellert, and Brand assert, that the smallest quantity of antimony mixed with iron prevents its being attracted by the magnet. Mr. Burgman used the following method to discover the substances which are attracted by the magnet, he placed the bodies which he intended to examine on pure water or very pure mercury,

mercury, either directly on the surface, or on a piece of paper, when on the approach of a strong magnet, they will be sensibly attracted, although the attraction could be discovered by no other method; in this way he found martial salts strongly attracted by the magnet. However, in general, iron when involved in a coating of saline matter is attracted less strongly in proportion as it is more intimately united to the salts. The attraction of iron is strongest when it is most deprived of oily, sulphureous, and saline particles. Spirit of nitre poured on iron which is acting on a magnetic needle, will diminish its action.

EXPERIMENT I.

Place a piece of iron on a cork, and put the cork into water, the piece of iron will be attracted by, and follow a magnet, in a pleasing manner. The tendency between the magnet and the iron is reciprocal; for if the magnet be put on the cork, it will follow the iron, in the same manner as this followed the magnet.

On this principle many ingenious and entertaining pieces of mechanism have been contrived. Small swans swimming in the water

have been made to point out the time of the day, &c.

EXPERIMENT II.

Place a magnet upon one of the brass stands, and present one end of a small needle towards it, holding the other end by a piece of thread, to prevent the needle fixing itself to the bar, and the needle will be pleasingly suspended in the air; the needle will remain suspended, although a piece of paper, glass, brass, &c. be introduced between the magnet and the needle.

EXPERIMENT III.

Suspend a magnet under the scale of a balance, and counterpoise it by weights in the other scale, then present a piece of iron towards the magnet, it will immediately descend, and, if the iron is not placed at too great a distance, will adhere to it: now suspend the iron under the scale instead of the magnet, then bring the latter towards it, and the iron will descend and adhere to the magnet.

EXPERIMENT IV.

Hold one end of the magnet at about half an inch from some steel filings, and these will fly to the magnet and form a kind of beard about the end of the magnet.

II. THERE ARE CERTAIN POINTS IN A MAGNET IN WHICH ITS VIRTUES SEEM AS IT WERE CONCENTRATED, WHICH ARE CALLED ITS POLES.

EXPERIMENT V.

Let a magnet be placed on one of the brass stands contained in the apparatus, and then try what number of iron balls it will sustain at different parts; it will be found to support most near the ends, evincing that the magnetic power is exerted there with the greatest force.

Take out the steel needle from the facturer, the two pillars *ab*, fig. 117, and place in its stead the needle, one half of which is made of steel, the other half of brass, the steel part of this needle is to be touched; on presenting the south end of a magnet to the end of the arch, this will
repel

repel the end of the needle to a certain degree, but on moving the magnet progressively forwards, the needle will gradually fall down till it comes to Zero. If the magnet is moved further the needle will be attracted.

TO FIND THE POLES OF A MAGNET.

EXPERIMENT VI.

Let a magnet be placed under one of those panes of glass which are contained in the bottom of the box; sift some steel filings on this glass, and then strike it gently with a key, in order to throw the glass into a vibratory motion; this will disengage the filings, and they will soon be arranged in a pleasing manner: those parts of the magnet from which the curves seem to take their rise, and over which the filings seem to be almost erect, are the poles of the magnet: or roll the magnet or loadstone in steel filings, which will adhere in a greater quantity, and more strongly to those parts, that are near the poles; and those particles which are over the poles will be perpendicular to the bar, the other particles will incline towards the poles. If a small needle be placed
in

in a glass ball and carried over the magnetic bar, it will stand perpendicular to the bar when it is over either of the poles, the various inclinations of a piece of steel, and at different parts of a magnet, may be pleasingly observed by this little apparatus.

In this, as well as many other magnetical experiments, a mechanical force is evidently exerted, detaching the particles of iron from one situation, removing them to another, and then retaining them there with considerable force.

E X P E R I M E N T VII.

The poles of a magnet may be ascertained with greater accuracy by means of the small dipping needle, fig. 117, place this on a magnet, and move it backwards and forwards till the needle is perpendicular to the magnet, it will then point directly to one of the poles. When it is between the north and south poles, so that their mutual actions balance each other the center of the needle will stand over what is called the equator of the magnet, and the needle will be exactly parallel to the bar. If it is then removed towards either pole, it will be differently inclined according to its distance from the poles.

EXPERIMENT VIII.

Hold a common small sewing needle (with some thread in its eye) near a magnet for a few seconds, then bring it gradually towards the middle of a magnetic bar, and the powers of the magnet will so far counteract the force of gravity as to keep it suspended in the air, in a position which is nearly parallel to that of the magnet.

There is no magnetical attraction without polarity; it is consequently absurd to suppose, that a magnet may have a strong attractive power, but a weak polarity, or directive power.

III. THE CONTRARY POLES OF TWO MAGNETS ATTRACT EACH OTHER.

THE NORTH POLES OF TWO MAGNETS, WHEN BROUGHT CONTIGUOUS, REPEL EACH OTHER.
THE SOUTH POLES ALSO, WHEN BROUGHT NEAR, REPEL EACH OTHER.

These phænomena are easily illustrated by a variety of pleasing experiments.

E X P E R I M E N T IX.

Suspend on a point a touched needle, then present towards its north pole the south pole of a magnet, and it will be attracted by, and fly towards it; present the other pole of the magnet, and the needle will fly from it.

E X P E R I M E N T X.

Strew a few steel filings upon a pane of glass, put either the north or south pole of one of the bars under the pane; the filings will rise upon the glass as the magnet approaches. Bring the same pole of the other bar directly over that under the glass, and when it is at a proper distance, the steel filings will drop flat on the pane.

E X P E R I M E N T XI.

Fix two needles horizontally in two pieces of cork, and put them in water; if the poles of the same name are placed together, they will mutually repel each other. If the poles of a contrary denomination are turned towards each other, they will be attracted and join.

EXPERIMENT XII.

Dip the north or south ends of two magnets in steel filings, which will hang in clusters from the end of the bars; bring the ends of the bars towards each other, and the steel filings on one bar, will recede from those on the other. Dip the south pole of one magnet, and the north pole of the other, into steel filings, then let the ends be brought near to each other, and the tufts of filings will unite, forming small circular arches.

IV. THE POWERS OR PROPERTIES OF A MAGNET MAY BE COMMUNICATED TO IRON OR STEEL.

To give a detail of the various processes which have been suggested, for the touching or communicating the properties of the magnet to iron or steel, would alone fill a volume, I shall therefore only give an account of two general and good methods which I presume will be found adequate to every common purpose.

1. Place two magnetic bars AB, fig. 100, in a line, with the north or marked end of one, opposed

opposed to the south or unmarked end of the other, but at such a distance from each other, that the magnet to be touched may rest with its marked end on the unmarked end of A, and its unmarked end on the marked end of B, then apply the north end of the magnet D and the south end of E to the middle of the bar C, the opposite ends being elevated as in the figure; draw D and E afunder along the bar C, one towards A, the other towards B, preserving the same elevation, remove D and E a foot or two from the bar when they are off the ends, then bring the north and south poles of these magnets together, and apply them again to the middle of the bar C as before; repeat the same process five or six times, then turn the bar, and touch the opposite surface in the same manner, and afterwards the two remaining surfaces, and by this means the bar will acquire a strong fixed magnetism.

2. Place the two bars which are to be touched parallel to each other, and then unite the ends by two pieces of soft iron called supporters, in order to preserve, during the operation, the circulation of the magnetic matter; the bars are to be placed so that the marked end D, fig. 101, may be opposite the unmarked end B, then place the two attracting poles G and I

on

on the middle of one of the bars to be touched, raising the ends so that the bars may form an obtuse angle of 100 or 120 degrees; the ends G and I of the bars are to be separated two or three tenths of an inch from each other. Keeping the bars in this position, move them slowly over the bar AB, from one end to the other, going from end to end about fifteen times. Having done this, change the poles of the bars*, and repeat the same operation on the bar CD, and then on the opposite faces of the bars; the touch, thus communicated, may be farther increased, by rubbing the different faces of the bars with sets of magnetic bars disposed as in fig. 102.

It seems, that in order to render steel magnetical, we must so dispose the pores that they may form contiguous tubes parallel to each other, capable of receiving the magnetic fluid, and then propagating and perpetuating its motion, so that the magnetic stream may enter with ease, and be made to circulate through it with the greatest force: to this end, it is necessary to be particularly attentive in the choice of the steel which is to be touched; the grain

* That is the marked end of one is always to be against the unmarked end of the other.

should

should be equal, small, homogenous, and without knots, that it may present a number of equal and uninterrupted channels to the fluid, from one end to the other: this is more immediately important in the choice of the steel for the needles of sea compasses, for, if the steel is impure, or the mode of touching improper, the needle may have different poles communicated to it, which will more or less impede the action of the principal needle according to their strength and situation.

The steel should be well tempered, that the pores may preserve for a long time the disposition they have received, and better resist those changes in their direction, to which iron and soft steel are liable. The difference in the nature of steel is exceeding great, as is easily proved by touching in the same manner, and with the same bars, two pieces of steel of equal size, but of different kind.

Steel that is hardened, receives a more perfect magnetism than soft steel, though it does not appear that they differ from each other in any thing but the arrangement of the parts; perhaps the soft steel contains phlogiston in its largest pores, while hardened steel contains it in the smaller. Iron, or steel, have very little air incorporated in their pores; when they are separated

parated from the ore, they are exposed to a most intense degree of heat, and most of the changes to which they are afterwards submitted, are effected in a red hot state. A piece of spring-tempered steel will not retain as much magnetism as hard steel, soft steel still less, and iron scarce retains any. From some experiments of Mr. Musschenbroek, it appears, that when iron is united with an acid, it will not become magnetical; but if the acid is separated, and the phlogiston restored, it will become as magnetical as ever.

The dimensions and shape of a magnet will make a difference in its force, therefore the bars to be touched, should neither be too long nor too short, but in proportion to the thickness; if they are too long, the passage of the magnetic matter coming out of one pole, and proceeding round the magnet to enter the other, will be impeded, and its velocity lessened. If they are too short, the fluid which comes out from one pole, will be repelled and thrown back by the other acting parts of the magnet, and thus be carried too far from the pole into which it ought to enter, and prevent the continued circulation of the magnetic matter. If they are too thin, then the number of pores are too few to receive a stream sufficiently strong to resist the

the

the obstacles in the external space; while, if they are too thick, the strait and regular direction of the channel is injured by the difficulty which takes place in the arrangement of the interior channels, as the magnetic matter has not sufficient force to penetrate the steel to any considerable depth, and thus injures the circulation of the fluid.

All the pieces should be well polished; it is of the greatest importance that the ends should be flat and true, so as to touch in as many points as is possible, the ends of soft iron which keep up the circulation. Inequalities on the faces, but principally near the poles, are to be avoided, as these occasion irregularities in the circulation, and thus diminish its velocity, which is one of the principal sources of magnetic power.

While the bars are touching, the ends of soft iron should be kept in constant contact with the bars, for a momentary separation is sufficient to destroy the effect of the operation, as the fluid will be instantly dispersed in the air.

The operator ought not to stop longer on the first bar than is necessary to open the pores, and to arrange them magnetically, passing immediately to the other, to form an opening for the fluid which issues from the first.

It is most advantageous to turn the bar that is quitted, while the touching magnets are placed on the other; by this means, the stream that is to be excited will dispose the channels of the first, and thus render the operation more efficacious; besides, by only turning one bar at a time, the touching bars need never be totally removed during the whole operation, a circumstance which will contribute to the strength of the magnet.

The touching bars should never be separated but at the equator of the magnet; and their motion over the others should be slow and regular.

The magnetic power of touching needles has been increased by leaving them for some time in linseed oil.

It may contribute to the effects of the operation if the bars A and B, fig. 100, are placed in the direction of the magnetic meridian, and are inclined to the horizon in an angle equal to the dip of the needle.

The fixed power, thus communicated to a magnet, is impaired if it is laid amongst iron, or by rust; it may be injured also by fire, as each of these circumstances will change, or confuse the direction of the magnetic stream.

Place a small magnetic needle on the point of one of the small stands, and put it between two mag-

magnetic bars, so that the north end of the bar may be near the south end of the needle; the small needle will, without any apparent cause, be thrown into a violent vibratory motion, and seem as it were animated, till it is saturated with magnetism, when it will become quiescent. The vibratory motion is probably occasioned by the irregularity of the impressions it receives from the magnetic fluid, and the difficulty that fluids find in entering the needle.

All causes that are capable of making the magnetic fluid move in a stream, will produce magnetism in those bodies which are properly qualified to receive it.

If bars of iron are heated, and then cooled equally, in various directions, as parallel, perpendicular, or inclined to the dipping needle, the polarity will be fixed according to their position, strongest when they are parallel to the dipping needle, and so less by degrees, till they are perpendicular to it, when they will have no fixed polarity; but if upon cooling a bar of iron in water, the under end is considerably hotter than the upper, and the upper end is cooled first, it will sometimes become the north pole, but not always. If iron, or steel, undergo a violent attrition in any one particular part, they will acquire a polarity; if the

iron is soft, the magnetism remains very little longer than while the heat continues. Lightning is the strongest power yet known in producing a stream of magnetism; it will, in an instant, render hardened steel strongly magnetical, and invert the poles of a magnetic needle.

To make a magnetical bar with several poles, place magnets at those parts where the poles are intended to be, the poles to be of a contrary name to those required, and if a south pole is fixed on one part, the two next places must have north poles set against them; consider each piece between the supporters as a separate magnet, and touch it accordingly.

EXPERIMENT XIII.

Take a piece of iron wire and bend it into the form of a staple, then touch the middle of the wire staple with only one of the poles of a magnet; without moving it backwards or forwards, the place where the magnet touches the wire will be one pole, and the two ends the other pole.

EXPERIMENT XIV.

Take any number of small steel bars, lay them end to end, and touch them while in this position;

tion ; when you separate them there will be a north and a south pole at every separation. See a similar experiment in the essay on electricity.

E X P E R I M E N T X V.

Touch a piece of iron wire, and then twist it about a large glass tube or any other cylindrical body, and the magnetic virtue will be so disturbed that in some parts it will attract, and in others repel the same pole of a magnetic needle.

T O T O U C H H O R S E S H O E M A G N E T S.

As these magnets from their form are capable of sustaining great weights, and maintaining the circulation of the magnetic fluid, I shall describe a convenient mode of touching them.

Place a pair of magnetic bars against the ends of the horseshoe magnet, with the south end of the bar against that end of the horseshoe, which is intended to be the north; and the north end of the other bar to that which is to be the south. The contact or lifter of soft iron to be placed at the other end of the bars. In this situation the magnetic fluid which circulates through the

bars will endeavour to force a passage through the horseshoe magnet, and thus facilitate the further communication of the magnetic virtue to the horseshoe magnet: to this end, rub the surfaces of the horseshoe with a pair of bars placed in the form of a compass turning the poles properly towards the poles of the horseshoe-magnet, being careful that these bars never touch the ends of the strait bars, as this would disturb the current of the magnetic fluid, and injure the operation. If the bars are separated suddenly from the horseshoe-magnet, its force will be considerably diminished; to prevent this, slip on the lifter or support to the end of the horseshoe-magnet, but in such a manner, however, that it may not touch the bars, the bars may then be taken away, the support slid to its place, and left there to strengthen the circulation of the fluid.

TO MAKE AN ARTIFICIAL LOADSTONE.

The late Dr. Gowin Knight possessed a surprising skill in magnetism, being able to communicate an extraordinary degree of attractive and repulsive power, and to alter or reverse the pole at pleasure, but as he refused to discover his
methods.

methods, these curious and valuable secrets died with him. In the LXIXth volume of the Philosophical Transactions, however, Mr. Benjamin Wilson has given a process, which discovers one of the leading principles of Dr. Knight's art; namely his method of making artificial loadstones.—To this end Dr. Knight provided himself with a sufficient quantity of clean iron filings, he put them into a large tub more than one third filled with water, he then with great labour worked the tub to and fro for many hours together, that the friction between the grains of iron by this treatment, might break off such smaller parts as would remain suspended in the water for a time. The obtaining these very small particles in sufficient quantity, seemed to him to be one of the principal desiderata in the experiment. The water being by this means rendered muddy, he poured the same into a clean iron vessel, leaving the filings behind, and when the water had stood long enough to become clear, he poured it out carefully, without disturbing such of the sediment as still remained, which now appeared reduced almost to an impalpable powder. This powder was afterwards removed into another vessel in order to dry it, but as he could not obtain a proper quantity thereof by this one process, he was obliged

to repeat the process many times. Having at last procured a sufficient quantity of this fine powder, the next thing was to make a paste of it; and that with some vehicle that should contain a sufficient quantity of the phlogistic principle, for this purpose he used linseed oil, and with those two ingredients he made a puff paste, and took particular care to kneed it well before he moulded it into convenient shapes. This paste was then put on wood or tiles at about a foot distance from a moderate fire, a great degree of heat frequently cracked the composition. The time for breaking or drying this paste was generally five or six hours, at which time they had generally attained a sufficient degree of hardness; when this was done, he gave them the magnetic virtue in any direction he pleased by placing them for a few seconds between his large magazine of artificial magnets, where they acquired such force, that when any of their pieces were held between two of his best ten guinea bars, with its poles purposely inverted, it immediately turned itself about to recover its natural direction, which the force of those very powerful bars were not able to counteract.

Rust of iron and common stone cemented together by any fat substance will also form an artificial loadstone.

O F A R M E D M A G N E T S.

In a strait loadstone or magnet, the stream is carried back on all sides in curved lines, but applying plates of soft iron to the poles of the magnet the direction of the fluid is changed, and it is conducted, united and condensed at the feet to the armour, so that if the feet are connected by another piece of iron which is called the lifter, the stream proceeding from one pole will be carried by the lifter to the other, which causes it to adhere with considerable force.

The armour should be made of soft homogenous iron, well fitted to the ends of the magnets, it should also be thicker in proportion as the distance of the poles from each other increases.

E X P E R I M E N T X V I.

Place an armed magnet under a glass plane which has been strewed over with steel filings, and these will arrange themselves in curves from one foot of the armour to the other.

Gaffendi invented a peculiar kind of armour, which was formed by piercing a magnet in the

direction of the axis, and placing a cylinder of iron in the hole, which augmented considerably the force of the magnet.

E X P E R I M E N T X V I I .

Mr. Van Swinden applied to an artificial magnet B. fig. 106, which supported four ounces by its north pole, another magnet B, so that its north pole was almost half an inch from the pole which supported the weight, and this pole immediately supported seven ounces. Du Hamel, Le Maire, &c. have also made many curious experiments on this head.

E X P E R I M E N T X V I I I .

Apply a bar of iron M N, fig. 107, to one foot of an armed magnet, and it is supported, approach the iron lifter of the magnet so that it may touch this bar and the armour; and the bar will fall.

E X P E R I M E N T X I X .

Apply to the pole B, fig. 108, a small piece of iron, nearly as much as that foot of the
armour

armour will sustain; let this piece of iron reach a little beyond the foot of the armour, then apply the lifter to the foot A, so that it may touch the piece of iron M; and the magnet will then support a considerable addition of weight.

E X P E R I M E N T XX.

If one end of the armour of a magnet only just sustains an iron ball, it will support two or three balls, if the contrary pole of a magnet is brought near it.

E X P E R I M E N T XXI.

Place an armed magnet at the magnetic equator and some distance from a magnetic needle, and mark how much it makes it deviate from its situation. Apply the contrary pole of another magnet to the end of the armed one, and the needle will be more strongly attracted.

V. LET AN IRON ROD BE EXACTLY BALANCED AND SUSPENDED ON A POINT, SO AS TO REVOLVE IN A PLANE PARALLEL TO THE HORIZON; COMMUNICATE THE MAGNETIC VIRTUE

VIRTUE TO THIS ROD, AND ONE EXTREMITY WILL BE ALWAYS DIRECTED TOWARDS THE NORTH.

E X P E R I M E N T XXII.

Place any of the untouched needles in the apparatus on a point, and it may be fixed, or will remain in any required situation; communicate the magnetic virtue to it, and it will no longer be indifferent as to its situation; but will fix upon one, in preference to any other, one end pointing towards the north, the other towards the south.

E X P E R I M E N T XXIII.

Float a magnet on water by means of cork, and it will place itself in the direction of the magnetic meridian. A terella floated on quicksilver will do the same, the magnetic axis conforming itself to the direction of the meridian.

It is not improbable, that in some future period, it may be discovered, that most bodies are possessed of a polarity, and will assume directions

rections relative to the various affinities of the elements of which they are compounded.

The directive power of a touched needle is of the greatest importance to mankind, as it enables the mariner to traverse the ocean, and thus unite the arts, manufactures, and knowledge of distant countries, together. The surveyor, the miner, and the astronomer, derive many advantages from this wonderful property.

The mariner's compass consists of three parts, the box, the card or fly, and the needle.

The card is a circle of stiff paper representing the horizon, with the points of the compass marked on it; the magnetical needle is fixed to the under side of this card; the center of the needle is perforated, and a cap, with a conical agate at its top, is fixed in this perforation; this cap is hung on a steel pin, which is fixed to the bottom of the box, so that the card hanging on the pin turns freely round its centre; one of the points being from the property of the needle always directed towards the north pole. The box which contains the card and needle, is a circular brass box hung within a square wooden one, by two concentric rings called jimbals, so fixed by cross centres to the two boxes, that the inner one shall retain an horizontal position in all motions of the ship. The top of the inner
box

box has a cover of glafs to prevent the card from being difturbed by the wind.*

It has been already obferved, that the anti-ents, do not feem to have been acquainted with the directive power of the magnet. The only thing that feems capable of being miftook for fome fuch knowledge, is what Jamblichus tells us in his life of Pythagoras, *That Pythagoras took from Abaris, the Hyperborean, his golden dart, without which it was impoffible for him to find his road.* But the authority of the writer, as well as the obfcurity of the paffage, prevents any conclufion being drawn from it.

Paul the Venetian, is faid to have introduced the ufe of the compafs in 1260, but this is faid not to have been his own invention, but borrowed from the Chinefe. P. Gaubil fays, the directive power of the needle was known to the Chinefe as early as the year A. D. 223, under the Dynafty of Haz. But the Abbi Renaudot in his Differtation on the Stone, when the Mahomedans went firft to China, has adduced

* Before the compafs was invented, the navigating of fhips was a tedious and precarious operation, and feldom performed out of fight of land; but this inftrument enables the mariner to travel over the feas almoft in as direct and true a tract as the land carrier directs his carriage in a well beaten road.

strong reasons to prove that the Chinese knew nothing of the mariners compass, till it was introduced there by the Europeans. Vertomanus affirms that A. D. 1500 he saw an East Indian pilot, direct his course by a compass framed, and fastened like those used in Europe; but this must be received with some caution, as Mr. Barlow in 1597, says that in a personal conference with two East Indians he was told by them that instead of our compass they made use of a magnetical needle of six inches or longer, set upon a pin in a dish of white China earth filled with water; that in the bottom of the dish they had two cross lines, to mark the four principal winds, and that the rest of the divisions were left to the skill of the pilot. But to return to Europe, Mr. Perrault in his parallel between the antients and the moderns has cited some verses of Guyot de Provins, who wrote in 1180, which shew distinctly that the mariners compass was known in the South of France at that time.

“ There is,” says he,

- “ A star that never moves,
- “ And an art that ne'er deceives,
- “ By virtue of the compass,
- “ An ugly black stone
- “ Which always attracts iron.”

Though by most writers the invention of the
com-

compass is ascribed to Flavio Goia of Analfi in Campanee, who lived about the year 1300. He is said to be the first that applied it to navigation in the Mediterranean.

Mr. de Lalande informs us that in "Le trèfor de Brunet," a manuscript in the French king's library, there is a passage which proves that the compass was made use of about the year 1260.

VI. THE NEEDLE OF THE MARINER'S COMPASS,
DOES NOT POINT EXACTLY TO THE NORTH,
BUT IS OBSERVED TO CHANGE ITS AZIMUTH,
POINTING SOMETIMES TOWARDS THE EAST,
AND SOMETIMES TO THE WEST OF THE
MERIDIAN.

Fig. 109, N S, represents the true meridian line; and E S, the east and west line which is perpendicular to it; now the magnetic needle A B, does not direct itself so as to coincide with the meridian line N S, but separates itself so as to form an angle N C B, at present of about 22 degrees.

This deviation from the meridian is called the variation of the needle, and is different at different parts of the world, being west at some places, east at others. and in parts where the
variation

variation is of the same name, its quantity is very different.

Though the directive power of the compass was applied to the purposes of navigation in the fourteenth and fifteenth century, it does not appear that there were any apprehensions during that time of its pointing otherways than due north and south.

The variation of the compass is said to have been first discovered by Columbus, in his voyage, the latter end of the fifteenth century, for the discovery of that part of the world which is now called the West Indies. But the first person who discovered that it was real, and was the same to all needles in the same place, is generally allowed to be Sebastian Cabot. This was about the year 1497.

After the variation was discovered by Cabot, it was thought, for a long time, to be invariably the same, at the same places, in all ages; but Mr. Gellibrand, about the year 1625, discovered that it was different at different times, in the same place.

From successive observations made afterwards, it appears that this deviation was not a constant quantity, but that it gradually diminished, and at last about 1660 it was found that the needle pointed due north at London, and has ever since
been

been increasing to the westward of the north. So that in any one place the variations have a kind of libratory motion, traversing through the north to unknown limits eastward and westward.

Dr. Halley in the last century published a theory of the variation of the compass. In this work, he supposes that there are four magnetic poles in the earth; two of which are fixed, and two moveable, by which he explains the different variation of the compass at different times in the same place. But it is impossible to apply exact calculations to so complicated an hypothesis.

Mr. Euler has shewn that two magnetic poles placed on the surface of the earth will sufficiently account for the singular figure assumed by the lines which pass through all the points of equal variation in the chart of Dr. Halley.

Mr. Euler first examines the case wherein the two magnetic poles are directly opposite; secondly, he places them in two opposite meridians but at unequal distances from the poles of the world; thirdly, he places them in the same meridian. Finally he considers them situated on two different meridians. These four cases may become equally important; because, if it is determined that there are only two magnetic poles, and that these poles change their situation,
it

it may hereafter be discovered that they pass through all the different positions.

Mr. Euler after having examined the different cases, finds that they also express the earth's magnetism, as represented in the chart published by Messrs. Mountaire and Dodson in 1744, particularly throughout Europe and North America, if the following principals are established.

Between the arctic pole and the magnetic pole $14^{\circ} 53'$. Between the antarctic and the other magnetic pole $29^{\circ} 23'$, $53^{\circ} 18'$ the angle at the north pole formed by the meridian's passing through the two magnetic poles, 250° the longitude of the meridian, which passes over the northern magnetic meridian.

I shall now give a short description of a *variation compass*, an instrument which is used to observe with accuracy, the deviation of the needle from the meridian. To this end it should possess the following properties:

1. That it may be easily and accurately placed in the meridian.
2. It should indicate small variations of the needle.
3. That the nonius which marks the small variation of the needle may be moved without disturbing it.
4. That the needle may be easily taken off and

inverted to discover whether the line marked on the needle coincides with the direction of magnetism in the needle.

Fig. 110 represents a variation compass which it is presumed will answer the foregoing purposes. It has a glass cover which is made to slide on or to be taken off occasionally, two graduated arches are fixed at each end of the box with a moveable nonius to each arch, the nonius are both moved by means of the milled nut A. without disturbing the situation of the needle.

The instrument is placed in the meridian by a telescope, whose line of collimation is parallel to the zero line of the instrument. The telescope is to be placed in two forks, in the manner advised by Mr. Magellan in his *Collection de differens Taites sur des instrumens D'Astronomie, &c. p. 227,* where the reader will find some observations on the adjustments, which are too long to be introduced in this essay. When the instrument is placed in the meridian, the method of observing is to move the northern nonius till the middle division coincides with the line on that end of the needle; and the nonius will then shew the angle that end of the needle makes with the meridian. If the line on the southern end of the needle coincides with the middle division of its nonius, the foregoing observation

Observation is sufficient; if not, the southern nonius must be moved till it coincides with this end of the needle, and the mean between the two numbers thus found will be the true angle.

The needle is so constructed, that it may be readily taken off the cap and inverted, in order to observe with the under face of the needle uppermost, to discover whether the line on the needle is parallel to the direction of the magnetism in the needle, and hence discover whether this line gives the true angle which the direction of magnetism makes with the meridian. Having made the observation as before with both ends of the needle, invert and observe what is now shewn by the inverted ends of the needle, and if the line is parallel to the direction of the magnetism in the needle, the mean of the observation with the inverted ends, will agree with the foregoing; on the other hand, if it is not parallel to the direction of magnetism, but makes it appear too much when the needle is upright, it will appear as much less when inverted, so that the mean of the foregoing means is the true angle which the needle makes with the zero line of the compass.

About the year 1722 and 1723, Mr. George Graham made a great number of observations on the diurnal variations of the magnetic needle.

In the year 1750, Mr. Wargentín took notice of the regular diurnal variation of the needle; and also of its being disturbed at the time of an aurora borealis. About the latter end of the year 1756, Mr. Canton began to make observations on the variation, and 1759 communicated the following valuable experiments to the Royal Society.

The observations were made by him for 603 days, on 574, out of these, the diurnal variation was regular. The absolute variation of the needle westward, was encreasing, from about eight or nine o'clock in the morning, till about one or two in the afternoon, when the needle became stationary for some time; after that the variation westward was decreasing, and the needle came back again to its former situation in the night; or by the next morning.

THE DIURNAL VARIATION IS IRREGULAR WHEN THE NEEDLE MOVES SLOWLY EASTWARD, IN THE LATTER PART OF THE MORNING, OR WESTWARD IN THE LATTER PART OF THE AFTERNOON; ALSO WHEN IT MOVES MUCH EITHER WAY AFTER NIGHT, OR SUDDENLY BOTH WAYS IN A SHORT TIME.

These irregularities seldom happen more than
once

once or twice in a month, and are always accompanied with an aurora borealis.

The attractive power of a magnet will decrease while it is heating, and increase while it is cooling; the greater the force of the same magnet, the more it will loose in a given degree of heat.

E X P E R I M E N T XXIV,

About ENE from a compass, a little more than three inches in diameter, Mr. Canton placed a small magnet two inches long, half an inch broad, and three-twentieths of an inch thick, parallel to the magnetic meridian; and at such a distance, that the power of the south end of the magnet was but just sufficient to keep the north end of the needle to the NE point, or to 45 degrees.

The magnet being covered by a brass weight of sixteen ounces, about two ounces of boiling water was poured into it, by which means the magnet was gradually heating for seven or eight minutes; and during that time, the needle moved about three quarters of a degree westward, and became stationary at $44^{\circ} \frac{1}{4}$; in nine minutes more, it came back a quarter of a degree, or to $44^{\circ} \frac{1}{2}$; but was some hours before it gained its former situation, and stood at 45° .

EXPERIMENT XXV.

On each side of the compass, and parallel to the magnetic meridian, he placed a strong magnet, of the size above-mentioned; so that the south ends of both the magnets acted equally on the north end of the needle, and kept it in the magnetic meridian; but if either of the magnets was removed, the needle was attracted by the other, so as to stand at 45 degrees. The magnets were both covered with brass weights of sixteen ounces each. Into the eastern weight about two ounces of boiling water was poured; and the needle in one minute moved half a degree, and continued moving westward for about seven minutes, when it arrived at $2^{\circ}\frac{3}{4}$. It was then stationary for some time; but, in twenty four minutes from the beginning, it came back to $2^{\circ}\frac{1}{2}$, and in fifty minutes to $2^{\circ}\frac{1}{4}$. He then filled the western weight with boiling water, and in one minute the needle came back to $1^{\circ}\frac{1}{4}$; in six minutes more it stood half a degree eastward; and after that, in about forty minutes, it returned to the magnetic north, or its first situation.

It is evident, that the magnetic parts of the earth in the north on the east side and the magnetic

netic parts of the earth in the north on the west side of the magnetic meridian, equally attract the north end of the needle. If then the eastern magnetic parts are heated faster by the sun in the morning, than the western, the needle will move westward, and the absolute variation will encrease; when the attracting parts of the earth on each side of the magnetic meridian have their heat increasing equally, the needle will be stationary, and the absolute variation will then be greatest; but, when the western magnetic parts are either heating faster, or cooling slower than the eastern, the needle will move eastward, or the absolute variation will decrease; and when the eastern and western magnetic parts are cooling equally fast, the needle will again be stationary, and the absolute variation will then be least. This may be still further illustrated, by placing the compass and two magnets, as in the last experiment, behind a screen near the middle of the day in summer; then, if the screen be so moved, that the sun may shine only on the eastern magnet, the needle will sensibly vary in its direction, and move towards the west; and if the eastern magnet be shaded, while the sun shines on the western, the needle will move the contrary way. By this theory, the diurnal variation in the summer ought to exceed that in

the winter ; and we accordingly find by observation, that the diurnal variation in the months of June and July, is almost double that of December and January.

The irregular diurnal variation must arise from some other cause than that of heat communicated by the sun ; and here we must have recourse to subterranean heat, which is generated without any regularity as to time, and which will, when it happens in the north, affect the attractive power of the magnetic parts of the earth on the north end of the needle. The Reverend Dr. Hales has a good observation on this head, in the Appendix to the second volume of his Statical Essays, which I shall here transcribe. “ That the warmth of the
 “ earth, at some depth under ground, has an
 “ influence in promoting a thaw, as well as
 “ the change of the weather from a freezing to
 “ a thawing state, is manifest from this obser-
 “ vation ; viz. Nov. 27, 1731, a little snow
 “ having fallen in the night, it was, by eleven
 “ the next morning, mostly melted away on
 “ the surface of the earth, except in several
 “ places in Busby-Park, where there were
 “ drains dug, and covered with earth, where
 “ the snow continued to lie, whether those
 “ drains were full of water, or dry ; as also
 “ where

“ where elm-pipes lay under-ground ; a plain
“ proof that these drains intercepted the
“ warmth of the earth from ascending from
“ greater depths below them ; for the snow lay
“ where the drain had more than four feet
“ depth of earth over it. It continued also to
“ lie on thatch, tiles, and the tops of walls.”

That the air nearest the earth will be most warmed by the heat of it, is obvious ; and this has frequently been taken notice of in the morning, before day, by means of thermometers at different distances from the ground, by the Reverend Dr. Miles, at Tooting, in Surrey ; and is mentioned in p. 526, of the 48th volume of the Philosophical Transactions.

The aurora borealis, which happens at the time the needle is disturbed by the heat of the earth, is supposed to be the electricity of the heated air above it ; and this will appear chiefly in the northern regions, as the alteration in the heat of those parts will be greatest. This hypothesis will not seem improbable, if it be considered, that electricity is now known to be the cause of thunder and lightning, that it has been extracted from the air at the time of an aurora borealis ; that the inhabitants of the northern countries observe the aurora to be remarkably strong, when a sudden thaw happens after severe

vere

vere cold weather ; and that the curious in these matters are now acquainted with a substance, that will, without friction, both emit and absorb the electrical fluid, only by the encrassation or diminution of its heat : for if the Tourmalin be placed on a plane piece of heated glass, or metal, so that each side of it, by being perpendicular to the surface of the heating body, may be equally heated, it will, while heating, have the electricity of one of its sides positive, and that of the other negative ; this will likewise be the case when it is taken out of boiling water, and suffered to cool ; but the side that was positive while it was heating, will be negative while it is cooling, and the side that was negative, will be positive.

IF A NEEDLE WHICH IS ACCURATELY BALANCED AND SUSPENDED SO AS TO TURN FREELY IN A VERTICAL PLANE BE RENDERED MAGNETICAL, THE NORTH POLE WILL BE DEPRESSED, AND THE SOUTH POLE ELEVATED ABOVE THE HORIZON: THIS PROPERTY IS CALLED THE DIP OF THE NEEDLE,

Fig. III. HO represents an horizontal line placed in the magnetic meridian *de*, a line at right
right

right angles to it, *b a* the situation a needle would take at London with respect to the horizon, making with the horizontal line an angle of 72 with the vertical line.

This property was discovered by Robert Norman, about the year 1576. We shall give the account of the discovery in his own words.

“Having, says he, made many and divers compasses, and using always to finish and end them before I touched the needle, I found continually that after I had touched the yrons with the stone that presently the north point thereof would bend or decline downwards under the horizon in some quantity; insomuch, that to the flie of the compass, which before was made equal, I was still constrained to put some small piece of wax in the south part thereof, to counterpoise this declining, and to make it equal again.

“Which effect having many times passed my hands without any great regard thereunto, as ignorant of any such property in the stone, and not before having heard nor read of any such matter: it chanced at length that there came to my hands an instrument to be made, with a needle of six inches long, which needle after I had polished, cut off at just length, and made to stand level upon the pin, so that nothing rested but only the touching of it with the stone: when I had touched

touched the same, presently the north part thereof declined down in such sort, that being constrained to cut away some of that part to make it equal again, in the end I cut it too short, and so spoiled the needle wherein I had taken so much pains.

“Hereby being stroken into some choler, I applied myself to seek further into this effect, and making certain learned and expert men (my friends) acquainted in this matter, they advised me to frame some instrument, to make some exact trial, how much the needle touched with the stone would decline, or what greatest angle it would make with the plain of the horizon. Thus far Mr. Norman.”

The dipping needle, represented fig. 112 was constructed by Dr. Lorimer, and is described in the Philosophical Transactions, vol. lxxv. part 1, page 81. It appears to me better calculated for the sea service than any other I have seen; it is less liable to be affected by the motion of the ship, than those which are suspended by gimbols fixed to the upper part of the instrument, besides other advantages which are derived from the double motion of the needle. The needle *ab* plays vertically upon its own axis, which has two conical points, which are inverted into the opposite sides of the upright parallelogram *cd*, into this parallel-

parallelogram, and at right angles to it, a slender brass circle fgb is fixed; this circle is silvered and graduated to every half degree upon which the needle shews the dip: this, for the sake of distinction, is called the circle of the magnetic inclination. The brass parallelogram, and consequently the circle of inclination also, turns horizontally upon two other points, the one above and the other below, in corresponding sockets in the parallelogram; these points are fixed in a vertical circle li which is of such a diameter as to allow the circle of inclination and parallelogram to move within it. This second circle may be called a general meridian; it is not graduated, but has a small brass weight fixed to the lower part of it, to keep it upright; and the circle itself is screwed at right angles, into another circle of equal external diameter which is silvered and graduated on the upper side to every half degree. It represents the horizon, as it swings freely upon gimbals, and is always nearly parallel to it.

The use of this instrument is very plain, as the inclination or dip is at any time apparent from inspection, and also the variation; if the frame is turned round till the great vertical lines meet exactly in the plane of the true meridian: for the circle of inclination being always in the needle's
vertical

vertical plane, the edge of it will evidently point out upon the horizon the variation E or W. But at sea, when there is not too much motion, you turn the frame round, till the vertical circle is in the plane of the sun's rays; that is till the shadow of one side of it just covers the other, and the edge of the circle will then give the magnetic amplitude, if the sun is rising or setting; but the azimuth at all times of the day; and the true amplitude or azimuth being found in the usual way, the difference is the variation. If the motion is considerable, observe the extremes of vibration, and take the mean for your magnetic amplitude or azimuth. This instrument has a constant power in itself, not only of setting itself in the proper position, but also of keeping itself so; or of restoring itself to the same situation, if at any time it has lost it; and it is curious to see how, by its double motion, it counteracts as it were, the rolling motion of the vessel. The degrees shewn by each end of the needle should be attended to, and the medium taken for the true dip or variation: also apply a good artificial magnet in such manner as to turn the parallelogram and circle of inclination half way round horizontally, so that the end of the axis of the needle which before pointed to west, shall now point to the east; and observe where

where the needle stands, and if it differs from the preceding observation, take the mean which will be found as near the truth as it is possible for any instrument to give.

DESCRIPTION OF A TERELLA AND OF THE MAGNETISM OF THE EARTH.

If a touched needle is placed near a magnet, its direction to the magnetic needle is suspended, and it assumes a direction relative to its situation and distance from the poles of the magnet.

EXPERIMENT XXVI.

Place a small needle on the pointed end of the brass stands, and then bring it near the magnet, and the needle will direct itself differently, according to the distance from the poles of a magnet; or,

Move the small dipping needle over a magnet, and by its varied situations it will illustrate the foregoing observation; or,

These relative situations and tendencies may be pleasingly observed by placing several touched needles round a magnet at the same time.

Fig. 113, A B represents a magnet B the north pole,

pole, A the south *ba, ba, ba*, &c. several small magnetic needles placed round the south pole of the magnetic *ab, ab, ab*, similar needles placed round the north end: *a* the north pole of these needles, *b* the south pole, *c* the center on which they turn. From this experiment may be derived others accurately investigating the nature of the magnetic curves.

Now, if the earth is a great magnet, or if a large magnet is placed within it, we see from the foregoing experiment, that magnetic needles placed on its surface would have different directions in different places, which is conformable to experience; and the apparent irregularities in the variation of the needle must be occasioned by the situation of the magnetic poles of the earth.

If the magnetic poles agreed with those of the earth there would be no variation, and the magnetic needle would point to the true north and south. If the axis of the magnetic poles passed through the center of the earth, it would be easy to assign the quantity of the variation at every place; but as this is not the case, to account regularly for the variation, it would be necessary to know the exact situation of the magnetic poles of the earth, their number, force, and distance from the real poles, whether they shift their place, and if they move, the quantity of motion every year.

Dr.

Dr. Haller supposed the earth to be an hollow sphere, with an internal nucleus in the cavity, he looked upon each part (the external and internal) to be a separate magnet endowed with two poles, and whose magnetical axis were not coincident. A compass needle on the surface of the globe would be acted upon in the same manner as it would be by a magnet with four poles, and thus explains the variation. But as the variation changes in process of time, he supposed that the poles do not keep the same position with respect to the surface of the earth and one another, and accounted for this motion, by supposing that the diurnal motion of the earth was impressed from without, and that the velocity of the internal part was less than the external. Therefore the nucleus would seem to turn slowly towards the west, and its poles describe smaller circles round the poles of the earth. And as the relative position of the four magnetical poles to each other, and to the poles of the earth is changed, so must the direction of the needle be varied.

Mr. Euler, who has considered the subject in every point of view, and treated it with greater perspicuity than any other writer, sees no reason for adopting so laborious and complicated an hypothesis. He thinks that every thing may be accounted for by two magnetic poles which are

not directly opposite to each other, or whose magnetic axis does not pass through the axis of the earth, whereby he avoids many difficulties with which the other theory is incumbered.

In order to investigate the phenomena of the variation and the dip of the needle, Gilbert, who supposed the earth to be a magnet, ground a loadstone into a round figure, like a globe, which he called a *terella* or little earth, as it exhibited in some degree the same phenomena which take place on the different parts of the surface of the earth. But little progress, however, was made with this instrument, as it did not sufficiently correspond with the nature of the earth's magnetism. It has since received several improvements from Mr. Magellan, but still remained very defective. The following improvement by Dr. Lorimer will, I hope, prove of essential service, in discovering the laws by which the mysterious properties of the magnet are directed.

This *terella* consists of a twelve inch terrestrial globe, so contrived that the two hemispheres may be separated or united at pleasure. Two strong artificial magnets are placed within the globe, in corresponding sockets at the center of each hemisphere, but so filled that while they act as
one

one magnet, their extremities or ends may be placed in various positions, and moveable to any latitude within 30° degrees of the pole, and are likewise moveable round the axis to any degree of latitude at pleasure.

Mr. Savery has adduced several instances to shew the force and action of the earth's magnetism; among others, that it will support small pieces of iron. He hung up a bar of iron, about five feet long, by a loop of small cord, at the upper end, and then carefully wiped the lower end, and the point of a nail, that there might be no dust or moisture to prevent a good contact; then holding the nail under the bar, with its point upward, he kept it close to the bar, holding only one finger under its head for the space of thirty or more seconds, then withdrawing his finger gently downwards that the nail might not vibrate; if it fell off, he wiped the point as before, and tried some other part of the plane at the bottom of the bar. If the ends are similar, and the bar has no permanent virtue, it is indifferent which end is downwards; if it has an imperfect degree of polarity, one end will answer better than the other.

E X P E R I M E N T XXVII.

The upper end *A* of a long iron rod, which has no fixed polarity, will attract the north end of a magnetic needle; the under end *B* repels the north end of the needle; invert the iron bar, and the end *B*, which is now the upper one, will attract the north pole of the needle that it repelled before; the case is the same, if the bar is placed horizontally in the magnetic meridian, the end towards the south will be a north pole.

Iron bars of windows, which have remained long in a vertical position, acquire a fixed polarity. Mr. Lewenhoek mentions an iron cross. Mr. Canton proposed to make artificial magnets without the assistance of natural ones; but in this he was mistaken, for his poker and tongs were natural magnets, and had their verticity fixed by being heated and cooled in a vertical position, and an iron or steel bar, though without a verticity, while it remains in that position exerts a polarity, and is able to communicate a fixed verticity to the small bar, and is therefore for the time a natural magnet. And further, every iron bar, from the largest size to a sixpenny nail will exert this power when treated as above mentioned,

ed. But how this power is raised so soon to a degree greatly exceeding that which communicated it we do not know; nor is it more easy to account for the facility with which the magnetic power is withdrawn by a friction contrary to that which gave it.

THE MAGNETIC MATTER MOVES IN A STREAM FROM ONE POLE TO THE OTHER, INTERNALLY, AND IS THEN CARRIED BACK IN CURVED LINES, EXTERNALLY, TILL IT ARRIVES AGAIN AT THE POLE, WHERE IT FIRST ENTERED, TO BE AGAIN ADMITTED.

E X P E R I M E N T XXVIII.

Put one of the glass panes over a magnetical bar, sift steel filings on the glass, then strike the glass gently, and the filings will dispose themselves in such a manner as to represent, with great exactness, the course of the magnetic matter. The curves by which it returns back to the pole, where it first entered, are also accurately expressed by the arrangement of the filings. The largest curves rise from one polar surface, and extend to the other; they are larger in proportion as they rise nearer the axis or center of the

polar surface; the curves which arise from the sides of a magnetical body, are interior to those which arise from the polar surfaces, and are smaller and smaller in proportion to their distance from the ends. That the magnetic matter does move back, in a direction contrary to that with which it passes through the magnetical body, is confirmed by its action on a small compass needle, when presented to it at different places. See fig. 103.

The greater the distance is between the poles of a magnet, the larger are the curves which arise from the polar surface.

THE IMMEDIATE CAUSE WHY TWO OR MORE
MAGNETICAL BODIES, ATTRACT EACH OTHER,
IS THE PASSAGE OF ONE AND THE SAME
MAGNETICAL STREAM THROUGH THEM.

EXPERIMENT XXIX.

Let two magnets be placed at some distance from each other, the south pole of one opposed to the north pole of the other, lay a pane of glass over them, and sprinkle it with steel filings, then strike the pane gently with a key, and the filings will arrange themselves in the direction of the
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the magnetic virtue. The filings which lay between the two polar surfaces, and near the common axis, are disposed in strait lines going from the north pole of one, to the south pole of the other: the pores being now in the same direction, so that the fluid which passes through *A B*, fig. 104, finds the pores at the pole *a* open to receive them, it will therefore pass through this, and coming out at *b* will turn towards *A*, to continue its stream through the magnet, and thus form one atmosphere or vortex, which pressed, on all sides, by the elastic force of the other, carries the magnets towards each other. At different distances from the axis the filings describe regular curve lines, which run from one pole to the other, and diverge from each other in moving from the south pole till they come half way, they then converge more and more, till they arrive at the north pole. If the opposed poles are distant from each other, some arches will pass from one pole to the other of the same magnet; fewer will be formed in this manner if they are brought nearer together, and more will proceed from one magnet to the other; the stream of the magnetic matter will seem more concentrated and abundant.

E X P E R I M E N T X X X .

While the magnets remain in the foregoing position, place a small untouched bar or needle in the stream of the magnetic virtue; this will pass through it, and give it a polarity in the direction of the stream.

E X P E R I M E N T X X X I .

On the same principal, a large key, or other untouched piece of iron, will attract and support a small piece of iron, while it is within the sphere of action of the pole of a magnet, but will let them fall when it is out of the magnetic stream.

E X P E R I M E N T X X X I I .

A ball of soft iron in contact with a magnet, will attract a second ball, and that a third, till the stream becomes too weak to support a greater weight.

E X P E R I M E N T X X X I I I .

Place two magnets parallel to the horizon with two poles of the same name opposed to each other, and their distance in proportion to the strength of the magnets; suspend a needle nicely balanced on a thread between them, and either pole will attract the needle notwithstanding their mutual repulsion.

E X P E R I M E N T X X X I V .

Put into motion one of the small whirligigs with an iron axis, and then take it up by a magnet; it will preserve its rotatory motion much longer than if it were left to whirl on the table; a second and a third whirligig may be suspended one under another, according to the strength of the magnet, and yet continue in motion.

E X P E R I M E N T X X X V .

Place a magnet upon each of the brass stands, with their poles of contrary names opposed to each other, and a pleasing chain of iron balls may
be

be suspended between them. Present either pole of another magnet towards them, and they will fall down.

EXPERIMENT XXXVI.

Place two bars in a line with the north end of one to the south end of the other, and about one third the length of the bar distance from each other, to which distance the power seems to be separated in most bars; place the glass panes on these bars, and then sift the filings over them, and they will range themselves between the bars, in the same manner they are ranged about the middle of each bar; shewing that when the powers are separated to this distance they act much in the same manner as when they are separated in the same bar.

MAGNETIC REPULSION ARISES FROM THE ACCUMULATION OF THE MAGNETIC FLUID, AND THE RESISTANCE FORMED TO ITS ENTRANCE IN THE MAGNET.

EXPERIMENT XXXVII.

If the two poles of the same name of two magnets,

nets are brought near to each other, and placed under a pane of glass, on which iron filings have been strewed, the filings will be disposed into curves, which seem to turn back from each other towards the opposite pole. The fluid which proceeds from B, fig. 103, meeting with resistance from the pores at D, is forced to turn back, and circulate round its own magnet, and thus form two atmospheres, which act against each other, in proportion to the force and quantity of the stream which passes through the magnets.

E X P E R I M E N T X X X V I I I .

Take a steel needle, with a very fine point, and rub it from the eye to the point five or six times with the north pole of a magnetic bar; the eye will be the north, and the point the south pole of the needle.

The attraction and repulsion of magnets is not hindered or increased by the interposition of any body whatever.

EXPERIMENT XXXIX.

Dip one point of the needle in steel filings, and it will take up a considerable quantity. Take the magnetic bar in one hand, and the needle with the filings in the other, hold them parallel to the horizon, with the point of the needle near the south pole of the magnet, and the steel filings will fall from the point of the needle; as soon as the filings drop off from the point, withdraw it from the sphere of action of the magnet, and the point will be so far deprived of its attractive quality, that it will not again attract the steel filings. If the needle is not taken away, but continues for a few minutes about half an inch from the bar, the polarity of the needle will be changed*.

EXPERIMENT XL.

Place two magnets close to each other, with the north and south poles conjoined together, in this situation the magnetic power is so far counteracted or condensed as to have very little effect

* Farther Proofs, &c. by Mr. Lyon, p. 60.

on iron, hardly sustaining the smallest piece, separate the magnets half an inch, and they will support a piece of iron, close them, and they will let it drop.

EXPERIMENT XLII.

Suspend two sewing needles from the pole of a magnet, and the needles will diverge, the repulsion will be augmented by the addition of another magnet, it is also increased by applying a bar of iron to the opposite pole of the magnet and diminished by applying it to the same.

EXPERIMENT XLIII.

Bring a bar of iron towards the extremity of the needles, and their repulsion will be augmented.

EXPERIMENT XLIV.

Suspend by a thread the light cylindrical bar *G D*, fig. 114, which has a round head at each end, and place it at a little distance from the mag-

net

net M, then bring an iron wire E E, near the lower head D, and the cylinder will be repelled, but will be attracted by the same wire if it is brought near the upper head.

EXPERIMENT XLIV.

Hang a number of balls to each other, by applying the first to the north pole of a magnet, present the south pole of another magnet to one of the middle balls, and all those below it will thereby be deprived of the magnetic stream, and fall asunder; the ball to which the magnet was applied will be attracted by it, and all the others will remain suspended. If the north end of the magnet be presented, then the ball, to which it is applied, will also drop.

A singular fact is related by some ancient writers on magnetism. That if two loadstones, a stronger and a weaker, have their repellent poles brought together, the weaker will have its power confused, and will not come to itself for some days; the polarity of the part, in contact, becomes inverted by the stronger power; but as that power reaches but a little way beyond the polar surface, the unaltered power, in the remaining part of the stone, is able, by its contra-

ry force, to restore the confused part of the stone in a few days.

It does not appear that there is any certain law of attraction peculiar to magnetism; for in different pairs of magnets, the force will vary at different distances. The magnetic attraction is not to be computed from the center of the magnets, but from the center of the pole*.

Though many experiments have been made to discover, whether the force by which two magnets are repelled or attracted, acts only to a certain distance; whether the degrees of its action within, and at this distance, is uniform or variable, and in what proportion, to the distances it increases or diminishes; yet we can only infer from them, that the magnetic power extends further at some times, than it does at others, and that the sphere of its action is variable.

The smaller the loadstone or the magnet is, the greater is its force, *cæteris paribus*, in proportion to its size. Though when the axis of a magnet is short, and of course its poles very near, their action on each other weakens the magnetic force. A variety of other causes will also occasion great irregularity in the attraction of magnetism. If one end of a magnet is dipped

* The magnetic effects of the contrary pole must be also considered in estimating the forces of magnetic attraction and repulsion.

in steel filings, we shall find that they are very seldom distributed with uniformity, but disposed in little tufts, some places more thick than others. The force of magnetic attraction between the same magnets, and at the same distance, may be varied by turning the magnets on their axis, and making different parts of the polar surfaces regard each other. If a strong magnet be applied to a weaker, a kind of repulsion seems to take place even between two poles of the same name, but its force is overpowered by the attraction of the stronger.

E X P E R I M E N T XLV.

If a touched needle is placed near a magnet, its direction to the magnetic meridian is suspended, and it assumes a direction relative to its situation and distance from the poles of the magnet. Place a small needle on the pointed end of one of the brass stands, and then bring it near the magnet, the needle will direct itself differently, according to its distance from the poles of the magnet. These relative situations and tendencies are more pleasingly observed by placing several touched needles round the bar at the same time. The motion of the small dipping needle further illustrates this proposition. From
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the three last experiments various others of considerable importance may be derived for accurately investigating the curves, according to which the magnets act, and illustrating further some of the intricate branches of magnetism.

The northern magnetism is destroyed by the communication of the southern, and *vice versa*. Hence it is clear, that the two magnetic powers counteract each other, and that if both be communicated to the same arm of a magnet, the magnetism acquired by the arm will be that of the strongest, and as the difference between the two powers.

Two straight magnets will not be weakened, if they are laid parallel to one another, with poles of the opposite denomination corresponding to each other, the ends being connected together by pieces of iron, which will keep up and facilitate the circulation of the magnetic fluid through them; but they should never be suffered to touch each other, except when they lie in the same direction, and with poles of contrary names.

A single straight magnet should be always kept with its south pole towards the north, or downwards, in the northern magnetic hemisphere, and *vice versa* in the southern hemisphere. Iron

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should

should never be lifted but by the south pole of a strait magnet in this hemisphere of the world.

Every kind of violent percussion weakens the power of a magnet; a strong magnet has been entirely deprived of its virtue by receiving several smart strokes of a hammer; indeed, whatever deranges, or disturbs the internal pores of a magnet, will injure its magnetic force, as the bending of touched iron, wires, &c.

EXPERIMENT XLVI.

Fill a small dry glass tube with iron filings, press them in rather close, and then touch the tube as if it was a steel bar, and the tube will attract a light needle, &c. shake the tube so that the situation of the filings may be disturbed, and the magnetic virtue will vanish.

EXPERIMENT XLVII.

But though a violent percussion will destroy a fixed magnenism, yet it will give polarity to an iron bar which had none before; for a few smart strokes of an hammer, on an iron bar, will give it a polarity, and by hitting first one end of the
bar,

bar, and then the other, while it is held in a vertical situation, the poles may be changed. Twist a long piece of iron wire backwards and forwards several times, then break it off at the twisted part, and the broken end will be magnetical.

E X P E R I M E N T XLVIII.

If a magnet be cut through the axis, the segments, which were joined before, will avoid and fly from each other.

E X P E R I M E N T XLIX.

If a magnet is divided by a section perpendicular to the axis, the parts which were joined before will have acquired contrary poles, one north, the other south, thus generating a new magnet at every section.

From these, and similar experiments, Mr. Eeles infers, that magnetism consists of two different distinct powers, which in their natural state are conjoined, and exert but little sensible action, and strongly attract each other at all times; but when they are separated by force,

they act like those of electricity; for if magnetism is excited in two different pieces of steel by the south pole of a magnet, the ends repel each other; but if one piece be excited by the north pole, and another by the south, they will attract each other. He further supposes, that a magnet attracts, and is attracted, not entirely according to its own strength, but according to the quantity of iron to be attracted; and that magnetism is a quality inherent in all iron, and of which it cannot be divested; for fire, which will destroy a fixed magnetism, does not deprive it of its natural quantity; on the contrary, it will give it a polarity, or fixed magnetism, according to the manner of heating or cooling of the iron.

The powers of magnetism, like those of electricity, are excited and separated by friction. This effect is wonderful in both, but more so in magnetism, where two powers, naturally attracting each other, remain separated in the same steel bar for many years, and yet they may be reduced to their natural state by the friction of two other magnets, acting in a contrary order to that by which the poles were originally separated.

Magnetism and electricity act strongest at corners, edges and points.

Magnetism may be communicated to a small steel needle, by passing the discharge of a large battery through it.

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The discharge of a battery through a small magnetic needle will sometimes destroy the magnetism, and at other times invert the poles of the magnet, which has also been frequently effected by lightning.

E X P E R I M E N T L.

Place a magnet *M*, fig. 115, at a given distance from the needle *A B*, fig. 115, that it makes the needle deviate from the meridian *N C* to *C B*, forming an angle *N C B* of 40 degrees. Now apply a bar of iron *I* to the magnet *M*, so that it may be perpendicular to it, but only covering half the breadth of the magnet, and the needle will go back to 30 degrees.

E X P E R I M E N T LI.

Place on the other side a bar *Y*, exactly similar to the bar *I*, and situated in the same manner; the needle will be very little affected, nay, by altering a little the situation of the bar the needle will not be at all affected by it.

Remove the bar *Y* from the magnet by a parallel motion, and the needle will approach

* See Essay on Electricity, p. 154.

still nearer the meridian, or, in other words, the action of the magnet will be weaker.

E X P E R I M E N T LII.

Place a magnet M, fig. 116, at some distance from the needle A B, and parallel to the magnetic meridian N S, the needle will deviate from its situation; now approach slowly towards the needle with a bar of iron, moving it in the equator of the needle, and the attraction of the needle to the magnet will be diminished, till a small part of *g* of the iron bar gets beyond the magnet; when its action will be considerably increased, and the needle more strongly attracted.

E X P E R I M E N T LIII.

Place a magnet so that it may attract a needle by its south pole, place one end of a bar of iron on the north pole of the magnet, and it will immediately attract the needle with more force.

E X P E R I M E N T LIV.

Place a strong magnet at some distance from a magnetic needle, so that it may either not act on
the

the needle or else make it deviate only a certain quantity from the meridian ; apply a bar of iron to the magnet, placing the bar between it and the needle, and the needle is immediately agitated.

E X P E R I M E N T L V.

Let the magnet be placed so near to the needle as to produce a sensible effect on it, then place the bar of iron on the pole of the magnet, describe a circle with the bar of iron, and the action of the magnet appears to be weakened, and the needle returns to the situation it had before the magnet was placed near it,

E X P E R I M E N T L V I.

Place a bar of iron between a magnet and the needle, so that it may be perpendicular to the magnet ; and the needle endeavours to recover its true situation, and even returns to it; if the bar be thick enough, or if two or three more are interposed*.

* Van Swinden, Memoire sur l'Electricité et le Magnetisme.

MAGNETICAL RECREATIONS.

BOX OF METALS.

THIS box contains five metallic tablets, of the same shape and size, that they may be placed indiscriminately into similar holes made in the bottom of a box. One of the tablets is gilt to represent gold, the second is silvered to represent silver, the third is of copper, the fourth of tin, and the fifth of lead. A small magnetic bar is inclosed in each of these pieces of metal, but is placed in a different situation in each piece. Another part of the apparatus is a small magnetic perspective, furnished at bottom with a magnetic needle, similar to those in small compasses; a piece of paper is pasted at the bottom of the perspective on the inside, on which is marked the initials of the different metals; these initials are so placed as to correspond with the magnets which are inclosed in the metals. If this perspective be placed over any of the tablets, so that the north and south line is perpendicular to the front of the box, the needle will point to the initial letter of the metal over which it is placed. Present the box to any one to dispose of
the

the tablets as he pleases, then to shut the box, and to return it you; when by means of the perspective you will be enabled to tell him how he has placed them.

COMMUNICATIVE MIRROR.

This apparatus consists of the perspective and stand represented N O L M K, fig. 118, four tablets as R, and a small box A B with a drawer to hold one of the tablets.

A small circular card with a touched needle, and on which are placed four pictures at right angles to each other, plays on a pivot in the foot M K of the perspective. Over part of this card is a hole, the center of which coincides with the center of the tube L N. An inclined mirror is fixed in the perspective N O, so as to be directly over the above-mentioned hole. There are also four tablets, on each of which a small picture is pasted similar to those on the card, and a magnetic bar inclosed in each. If one of these is placed in the drawer of the box A B, and the perspective over that as in fig. 118, and the fore part is then pressed down to disengage a spring which is within the foot, then will the card place itself so as to correspond with the tablet in the drawer, and a similar figure will be seen by looking in
at

at the eye end of the perspective. Consequently if you present the four tablets to any person, desiring him to place any one of them in the drawer and conceal the others, then shut the drawer and return it. Now place the perspective in a box, and pressing the part T as abovementioned, and you may shew him the figure on the tablet he placed in the drawer, in the eye end of the perspective.

These, and many other recreations of this kind will be found in "Hooper's Rational Recreations," the greater part of which I have executed with improvements.

OF THE ACTION OF THE MAGNETIC ATMOSPHERE.

The pole of a magnet produces on the part of a bar to which it is applied, the pole of a contrary name: therefore, if two bars fully touched have the poles of the same name joined together, they tend to produce on each other a force of a contrary name to that with which they are endowed; and this effect will diminish the polar force of each bar; consequently the magnetic force of each longitudinal element of an artificial magnet diminishes as its bulk is increased, and the total force

force of two magnets fully touched, and of the same length but unequal in bulk, will be in a less ratio than that of their mafs.

If the magnet does not touch the bar, but is held at some distance from it, the phenomena will be the same; but the bar will acquire less magnetism than when it was in contact with the magnet.

Each point of a magnet may be looked on as the pole of a smaller magnet, tending to produce on the points of the magnet a force contrary to its own. The effect of this tendency will be greater, in proportion to the force of the point, and its nearness to those points on which it acts; and the force of a magnet will depend on the reciprocal action of these points on each other.

The action of a magnetic point is increased according as the intensity of the other points on it increases, as their number is greater, and their distance from it is less. The more the magnetic points are (from the figure of the magnet) brought together, and the stronger their action on each other in order to destroy their reciprocal forces, the weaker is the force of each point.

Hence in two bars of the same weight and length the broadest will be the most powerful, because its longitudinal fibres are more insulated.

If a bar is divided into two parts, each will receive a greater degree of magnetism than when they were united.

From the same analogy we may infer, that the exterior points and edges of a magnet will have more power than the interior ones of the same bar, as they are also more insulated.

A bar is said to be saturated with magnetism, if when suspended freely in an horizontal position it continues to make the same number of oscillations in the same time, though continued to be rubbed with a magnet. As each point of a magnet tends to destroy the magnetism of the neighbouring parts, the bar appears to be in a forced or unnatural state, and the magnetic fluid endeavours to spread itself over the bar in an uniform manner, and consequently to weaken and destroy its powers. The greater part of what has been said on the action of the particles of magnetism on each other will be found equally applicable to electricity.

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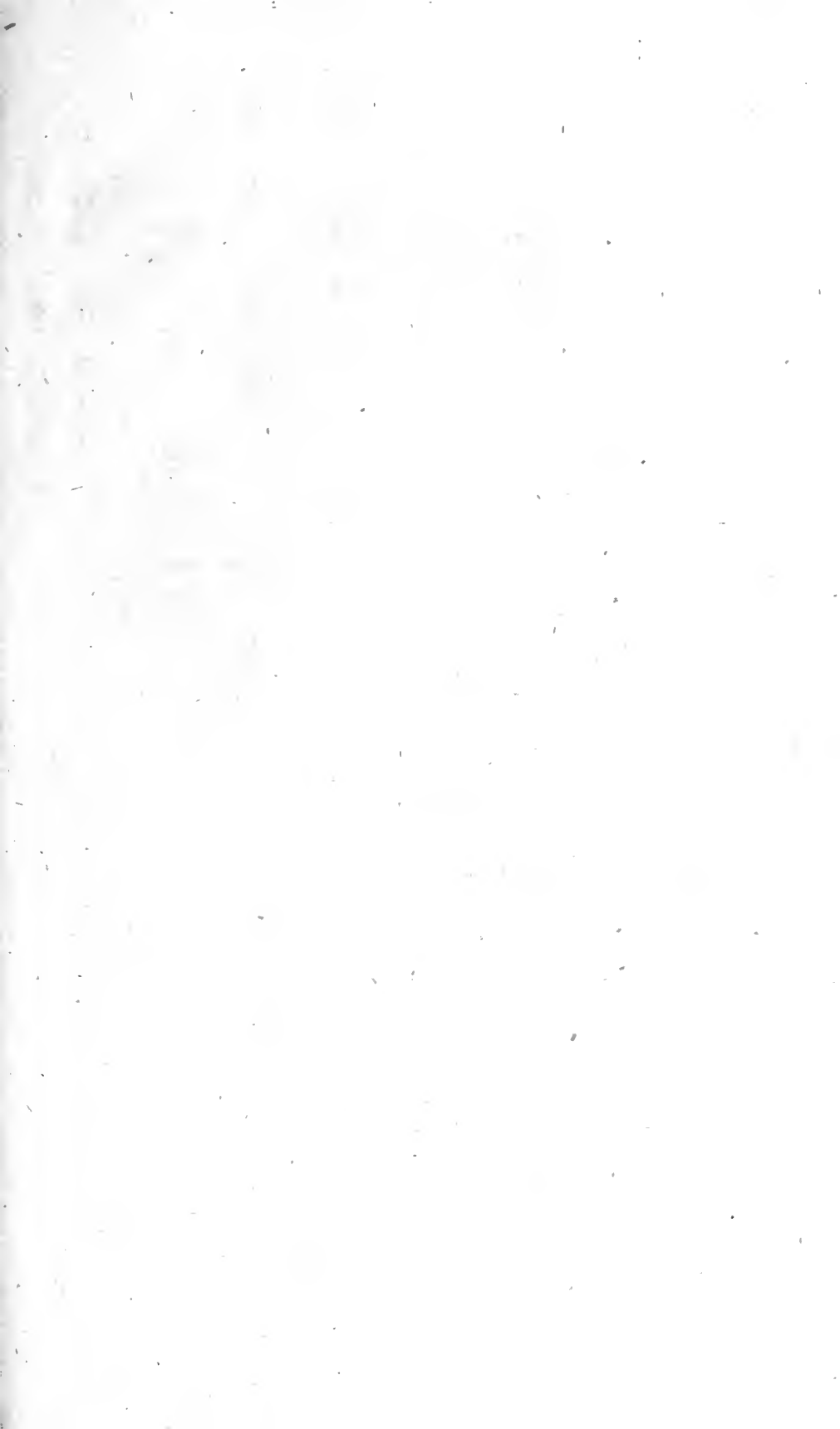




Fig. 1.

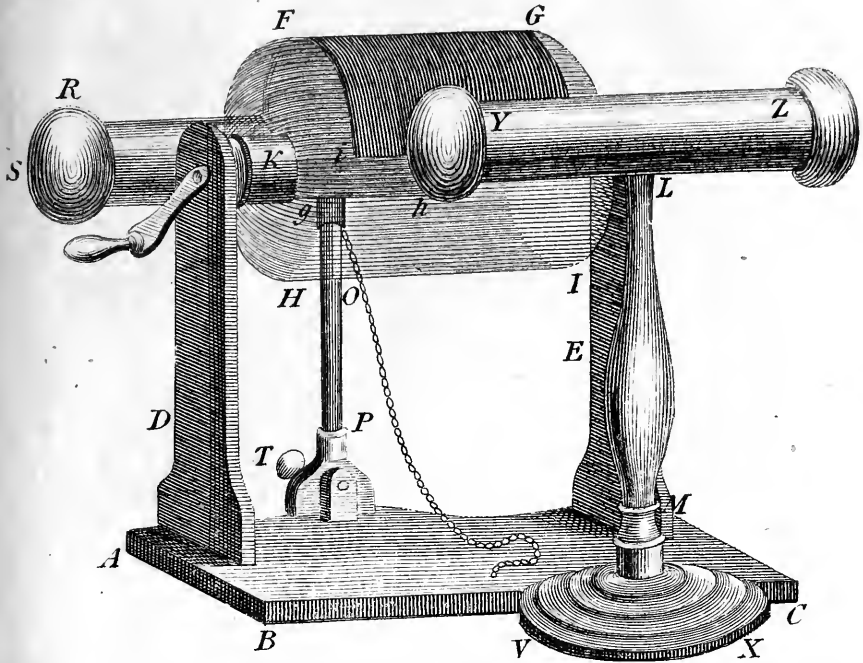
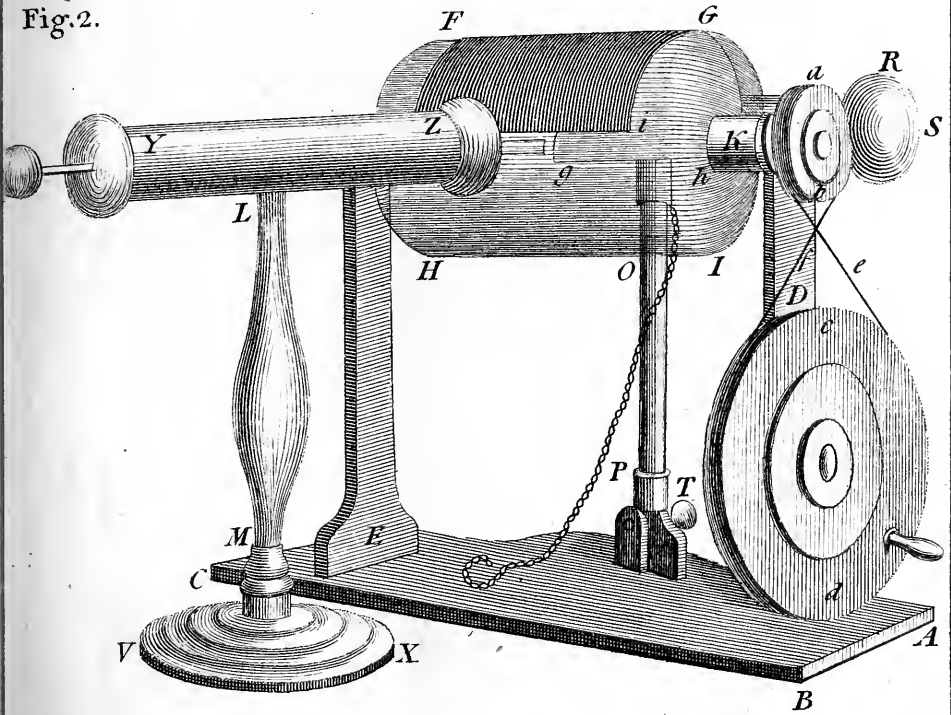
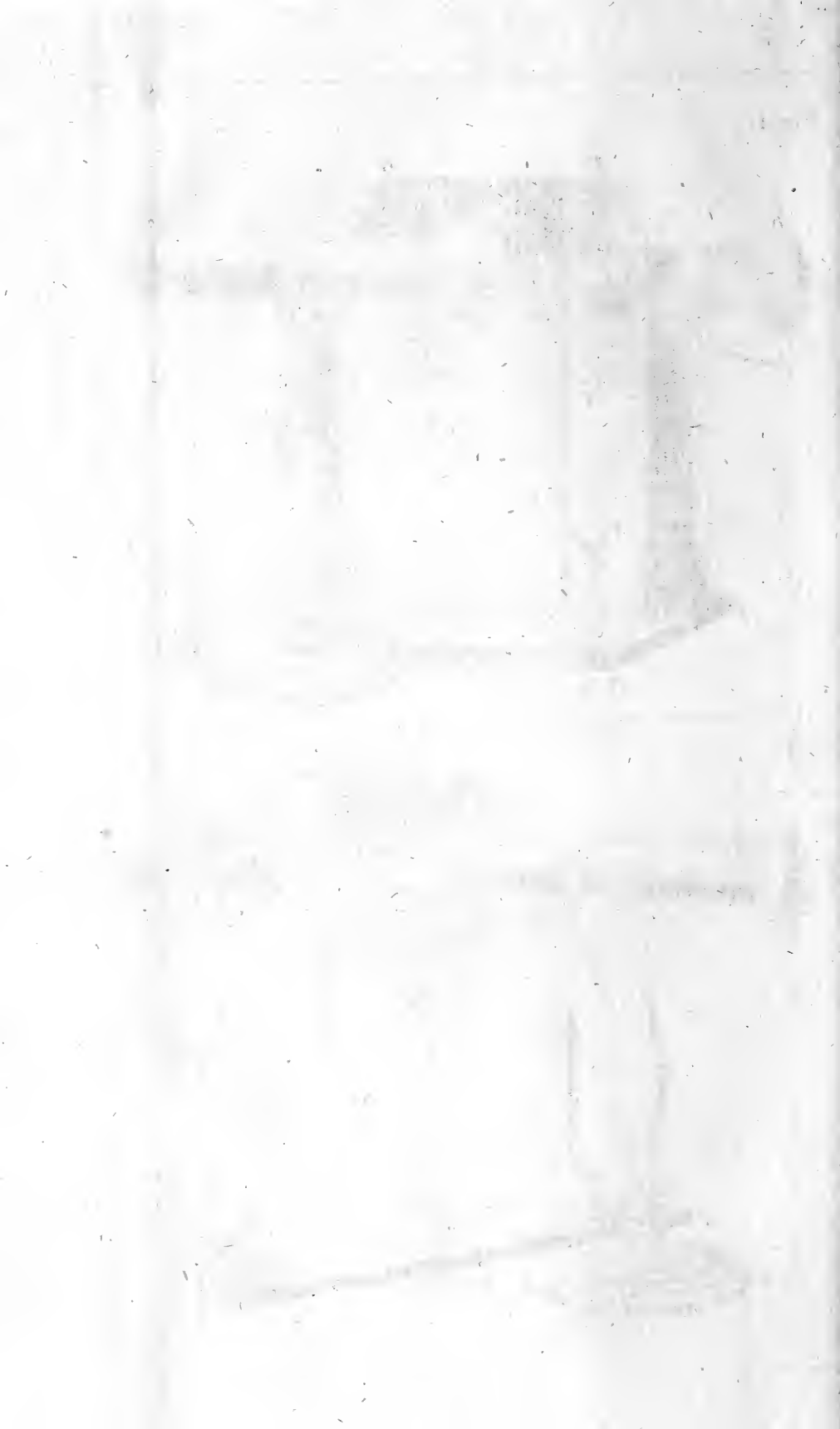


Fig. 2.





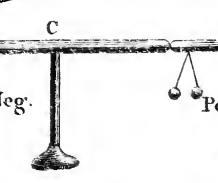
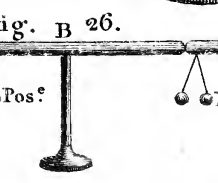
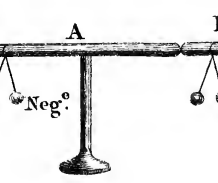
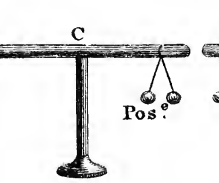
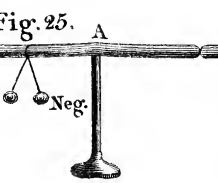
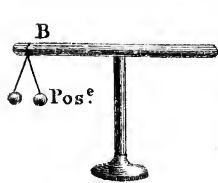
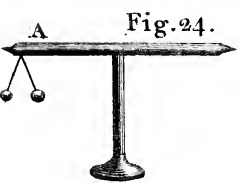
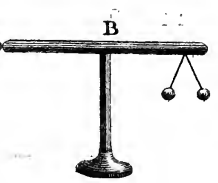
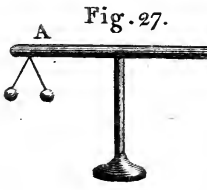
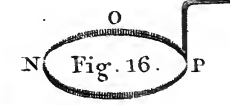
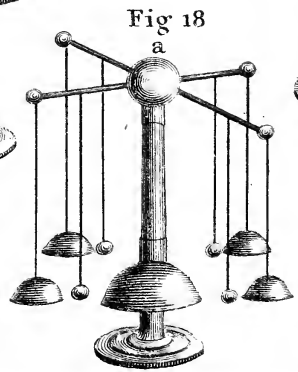
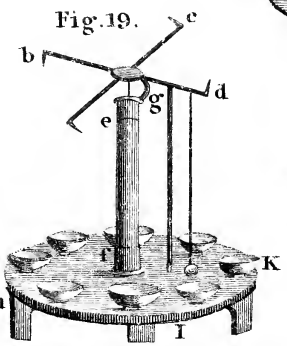
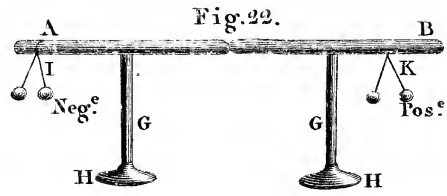
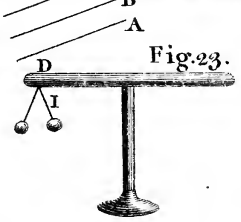
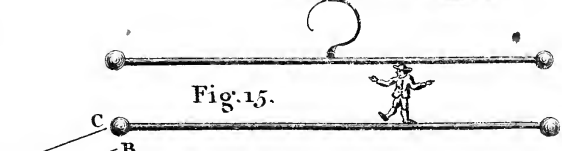
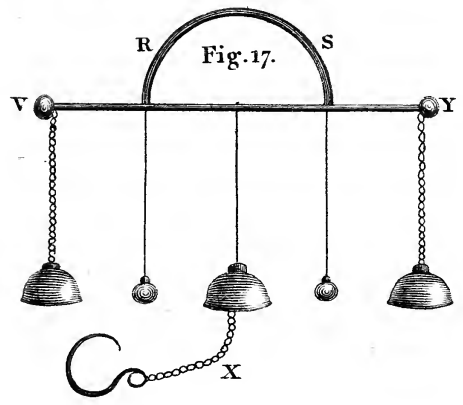
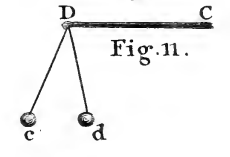
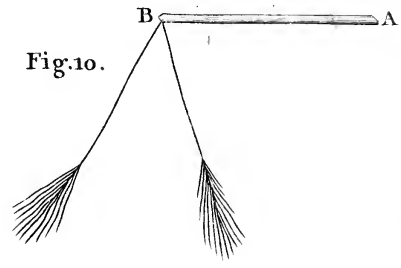
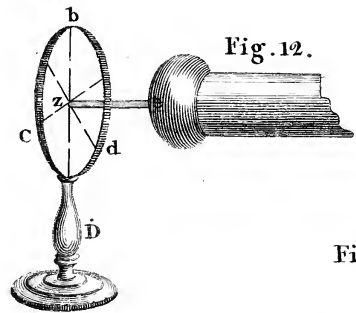
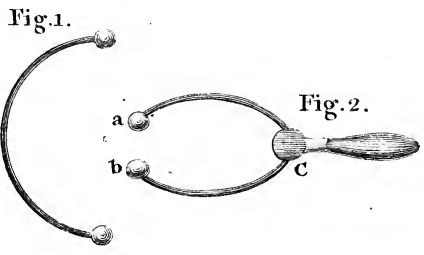
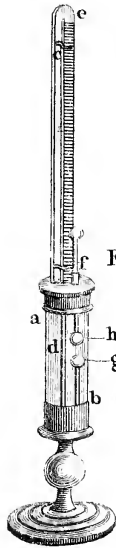
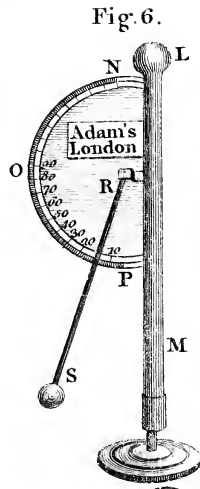
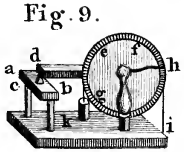
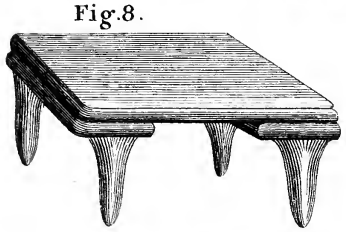
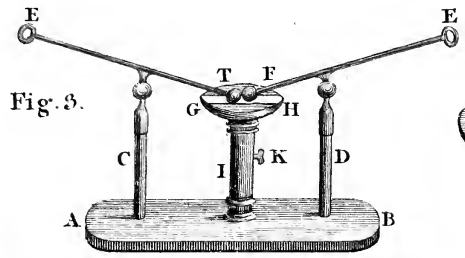




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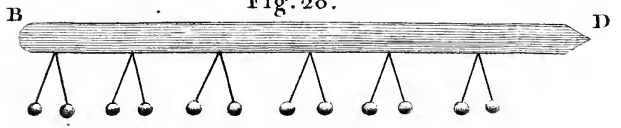


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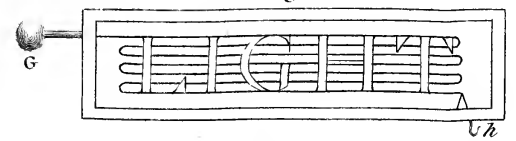


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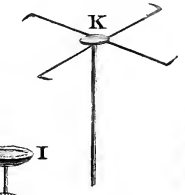


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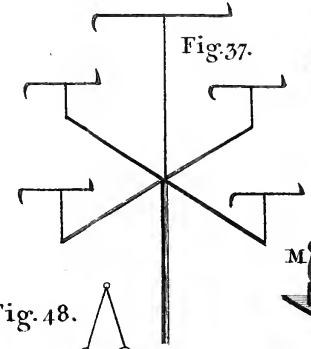


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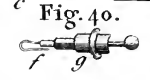


Fig. 41.

Fig. 29.

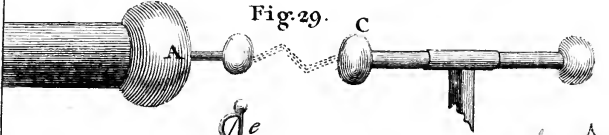


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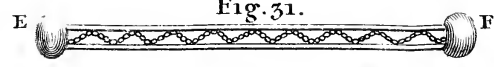


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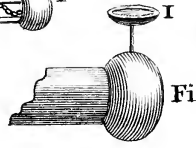


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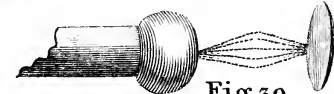


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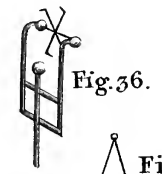


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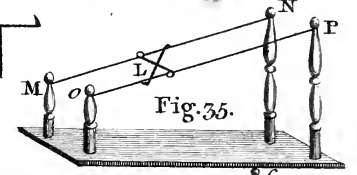


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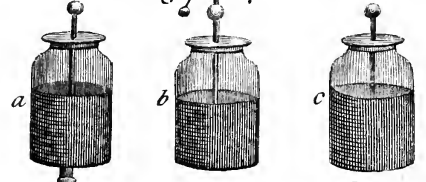


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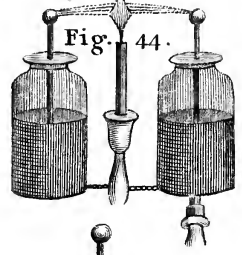


Fig. 47.



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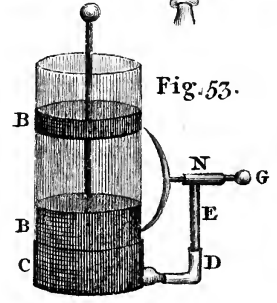


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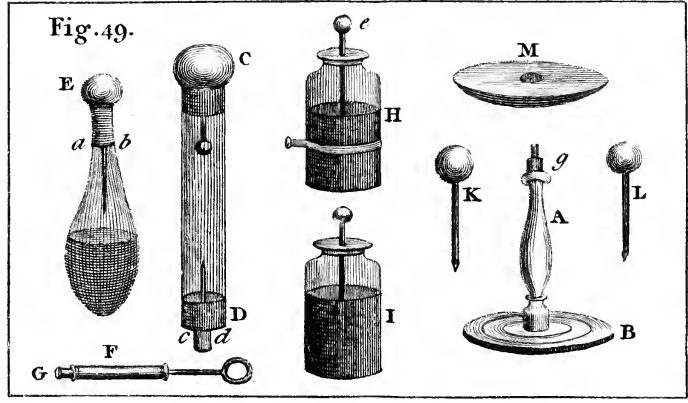


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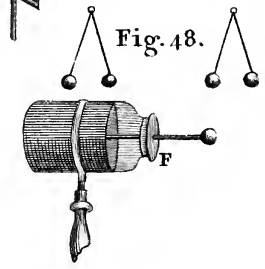


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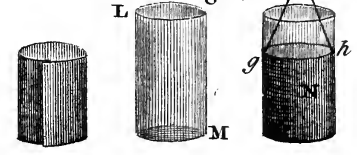


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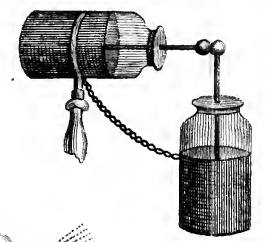


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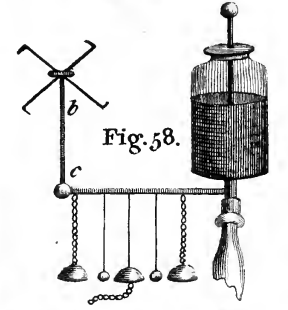


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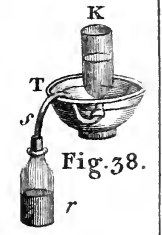


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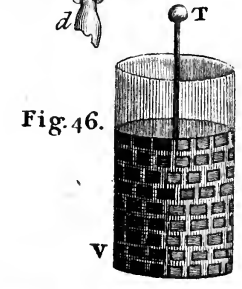


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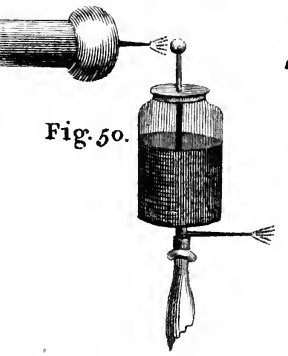


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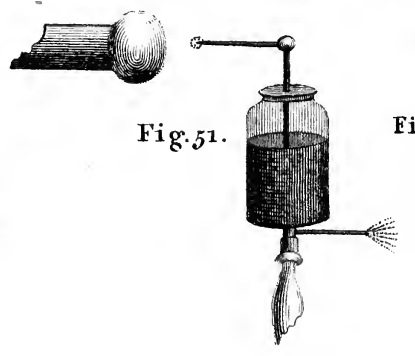


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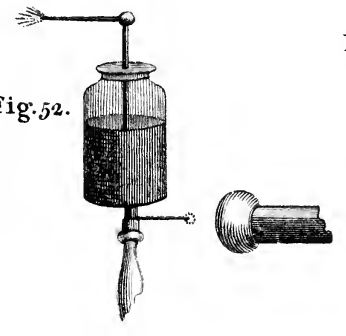


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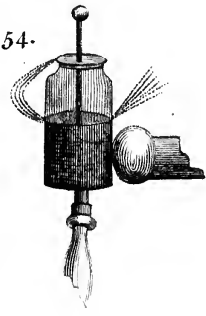


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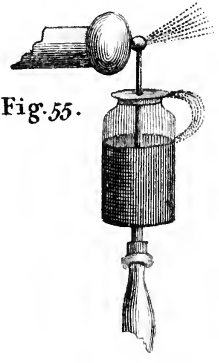


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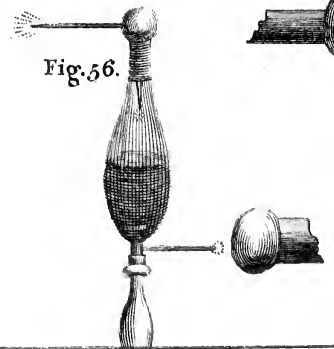


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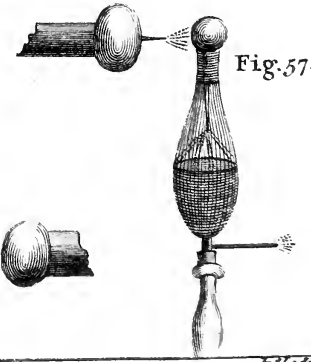




Fig. 59. Fig. 60. Fig. 61. Fig. 62.

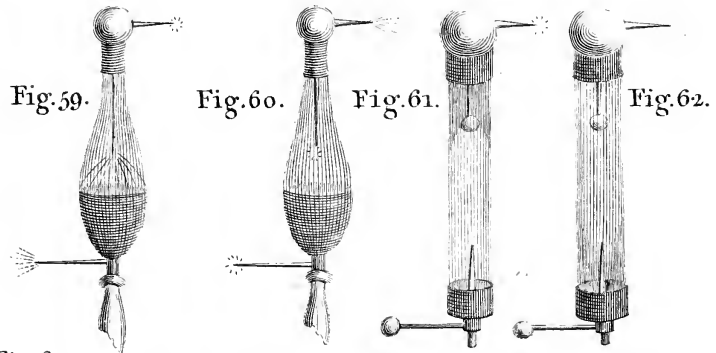


Fig. 64. Fig. 63.

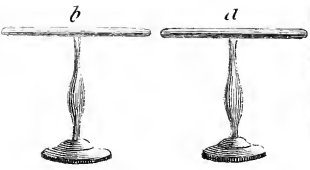
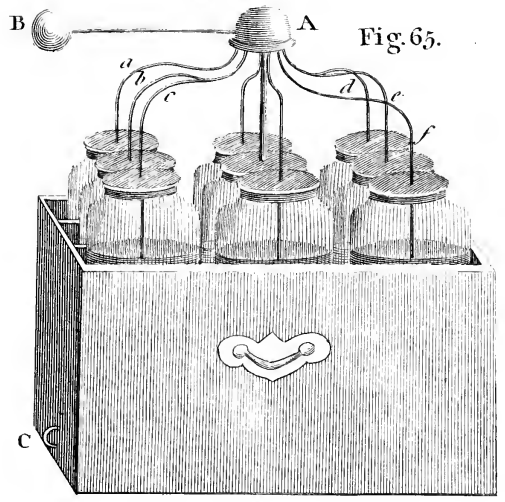
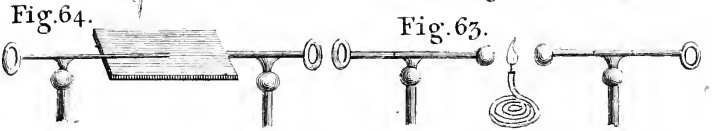


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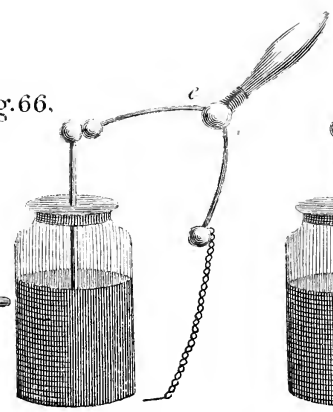


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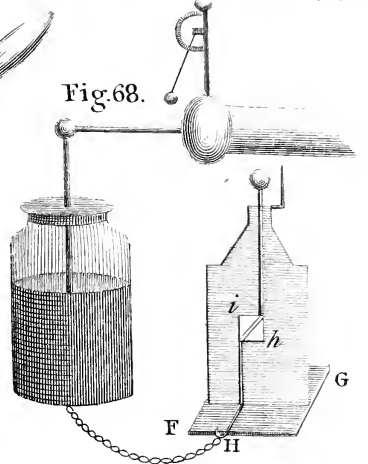


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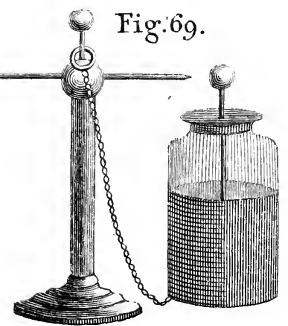


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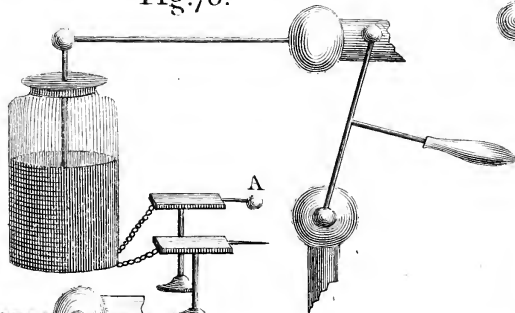


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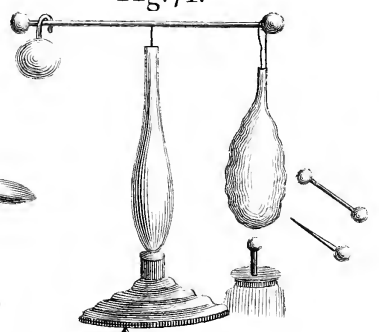


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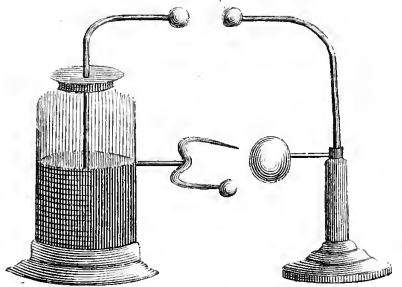


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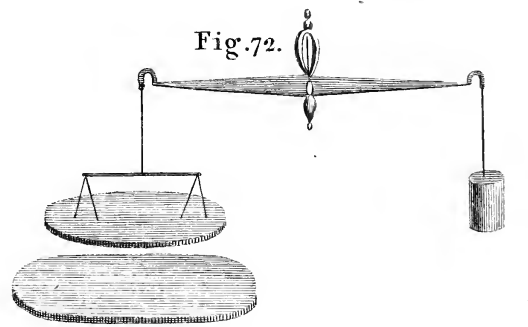


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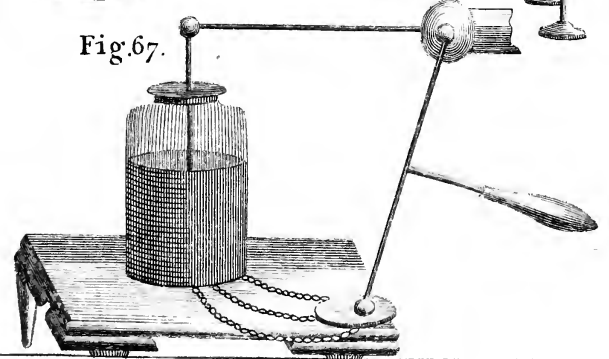


Fig. 77.



Fig. 74.



Fig. 75.

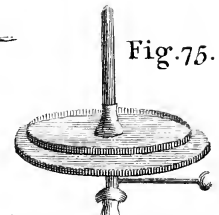


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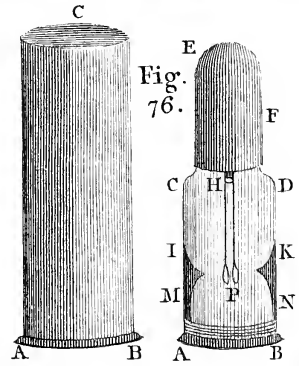
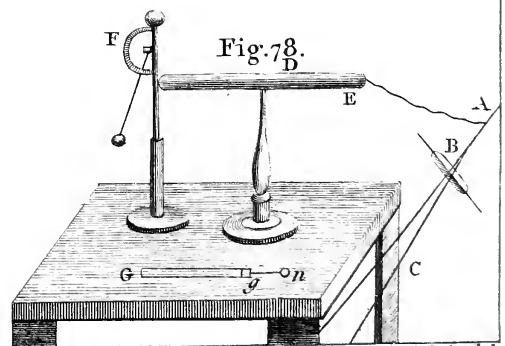
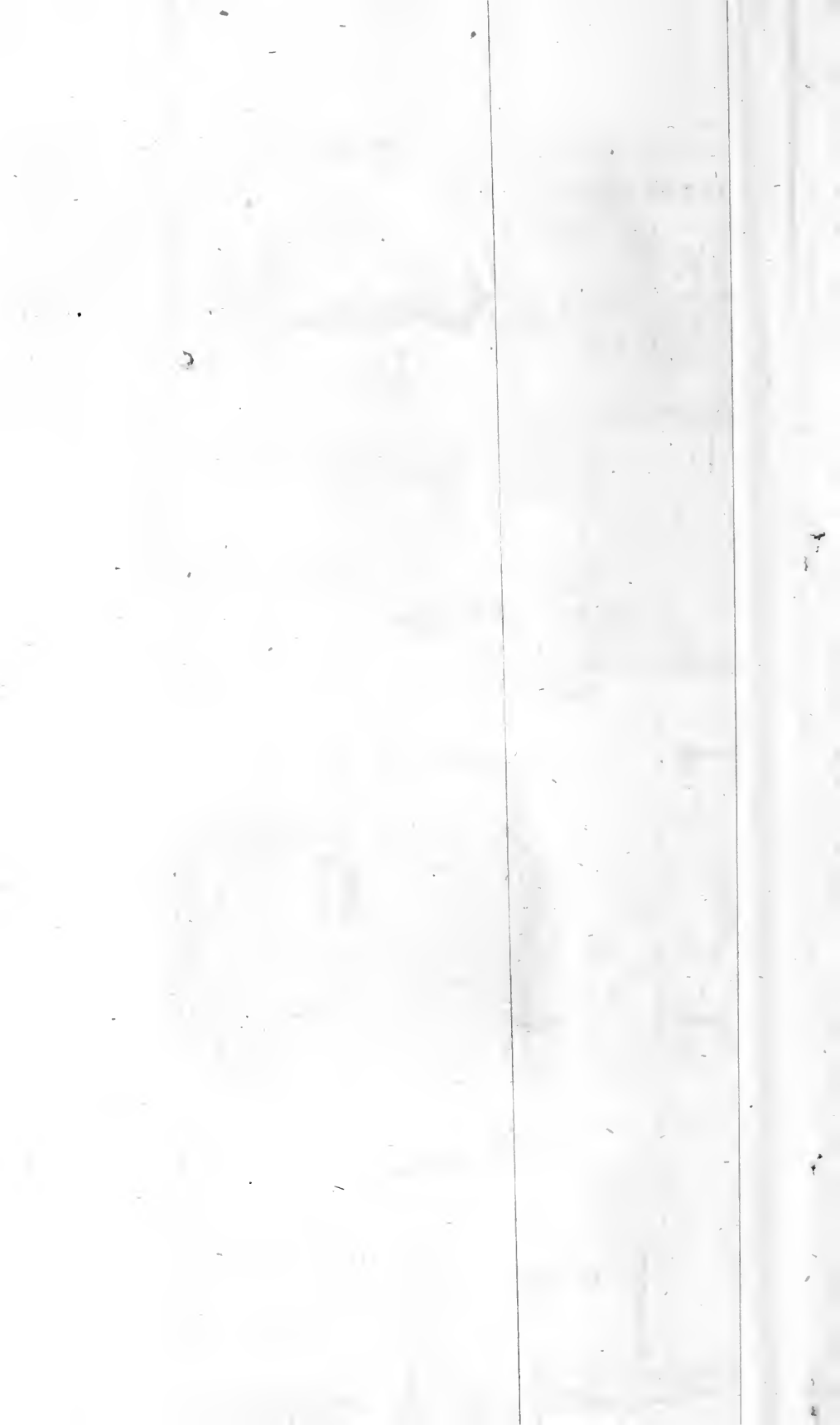


Fig. 78.





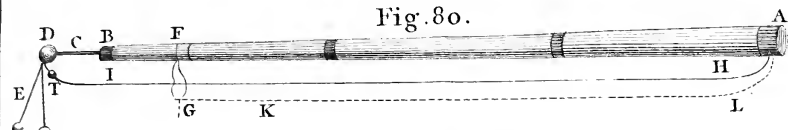


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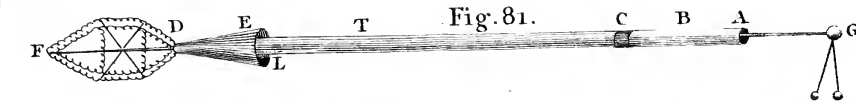


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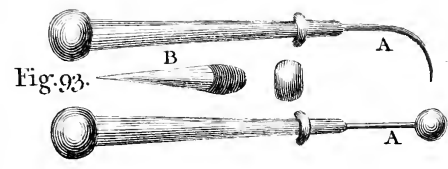


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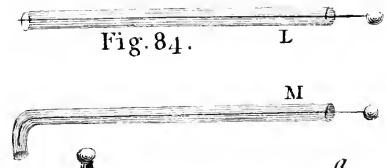


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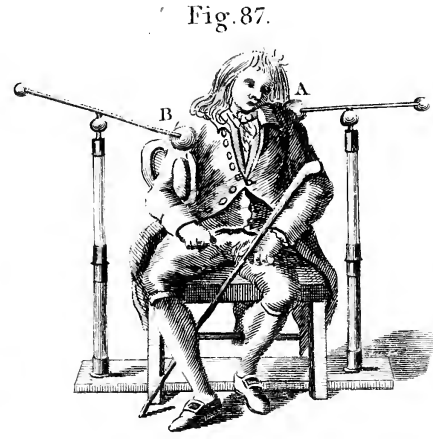


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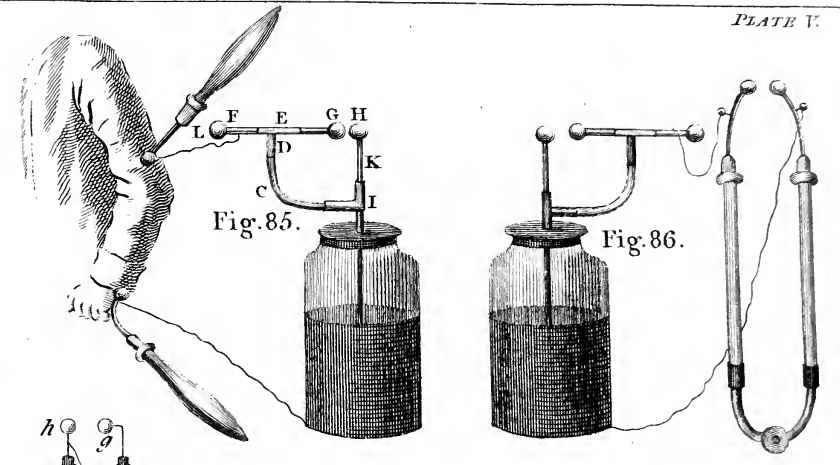


Fig. 85.

Fig. 86.

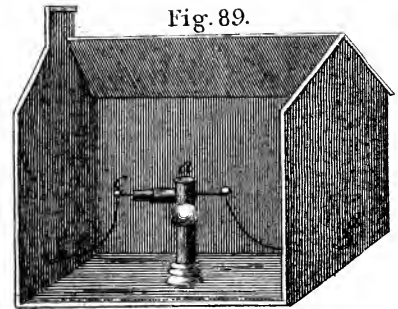


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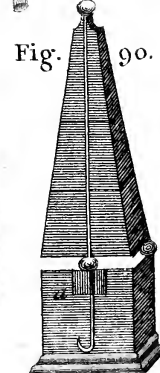


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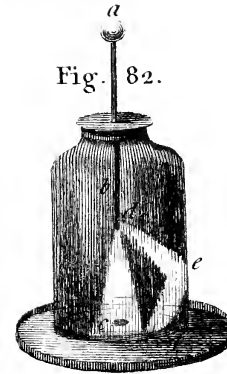


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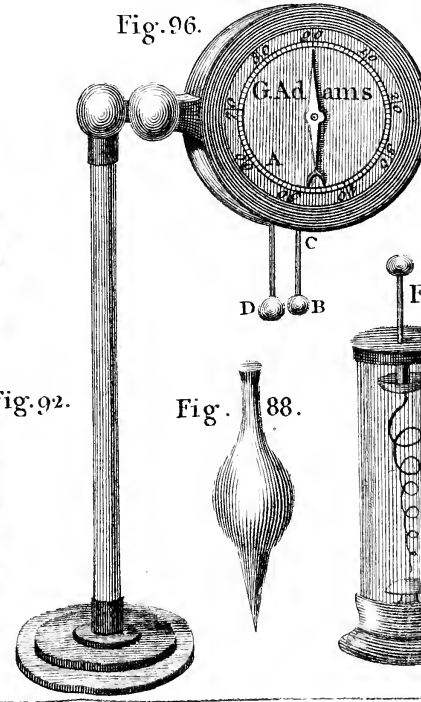


Fig. 96.



Fig. 19.



Fig. 94.

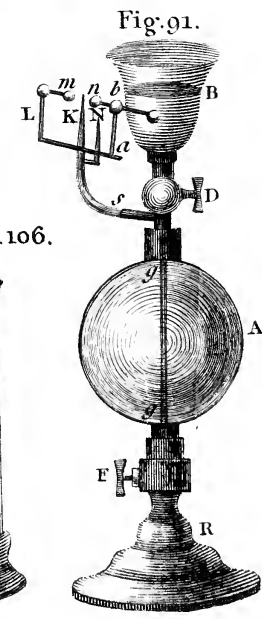


Fig. 91.



Fig. 97.

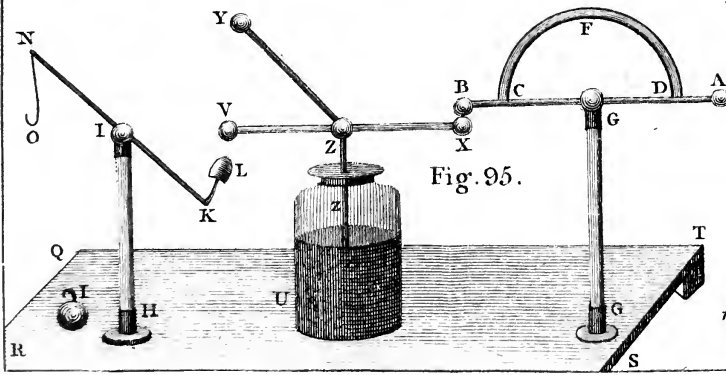


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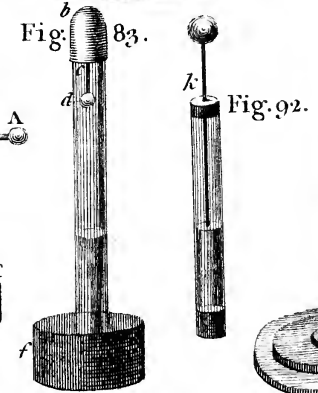


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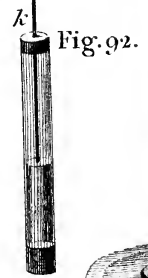


Fig. 92.



Fig. 88.

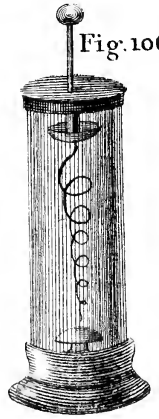


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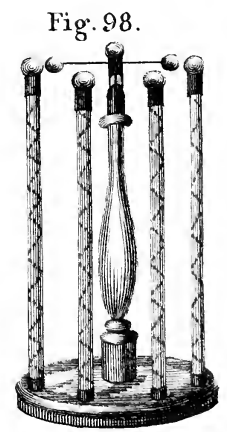


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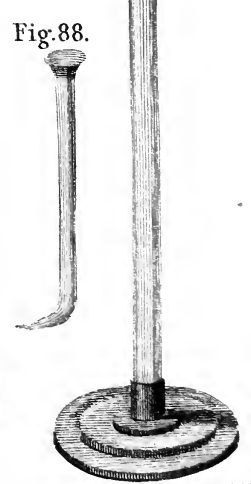


Fig. 88.



Fig. 100.

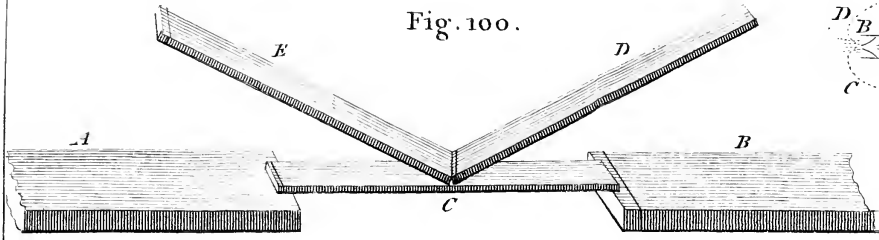


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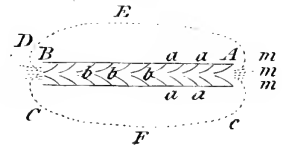


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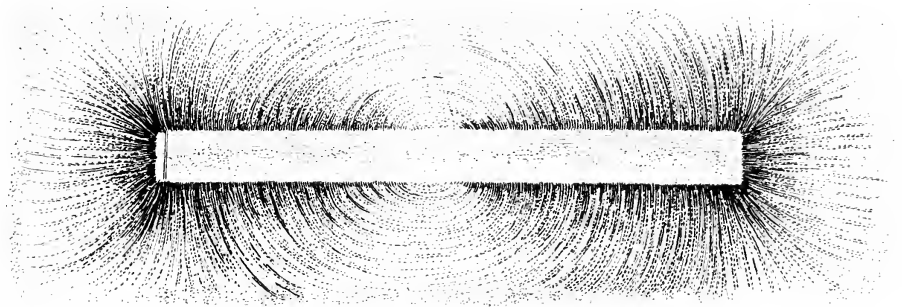


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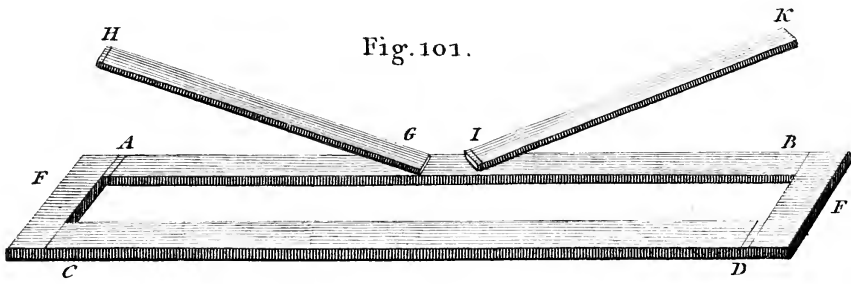


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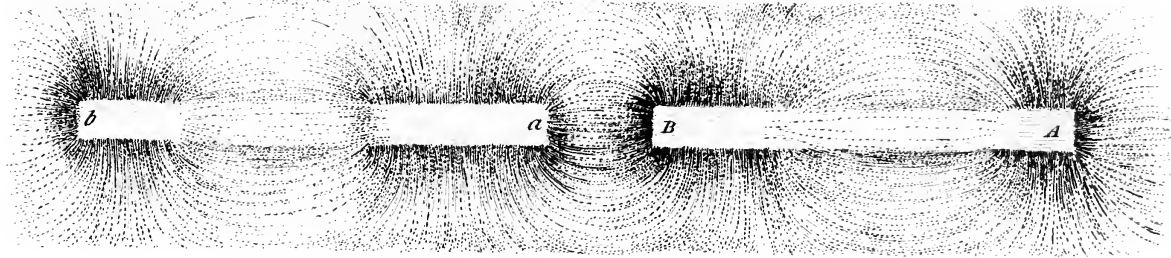


Fig. 102.

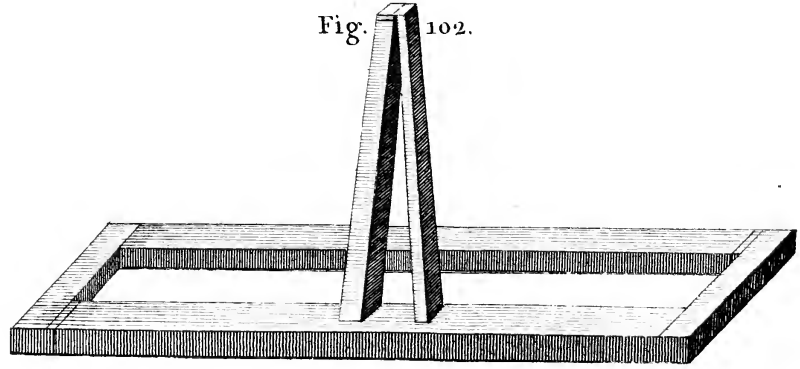
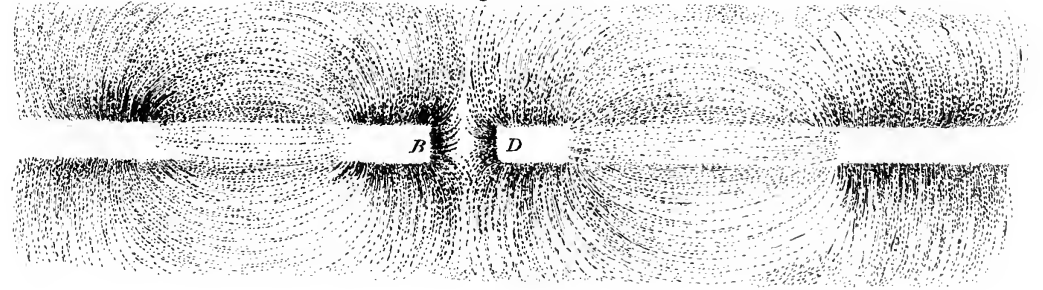
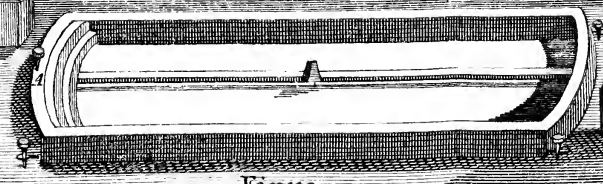
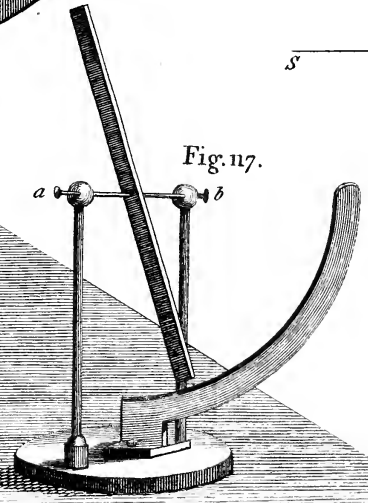
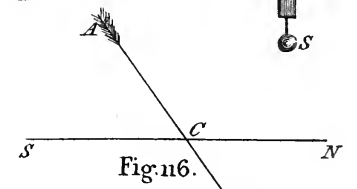
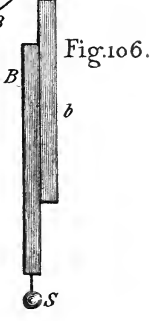
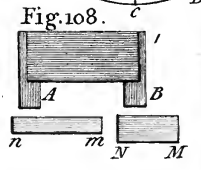
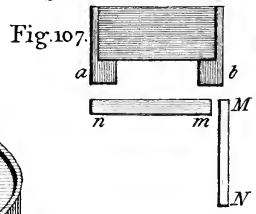
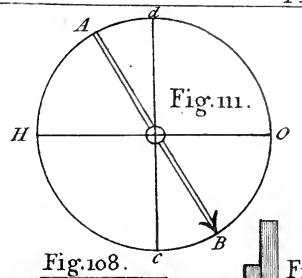
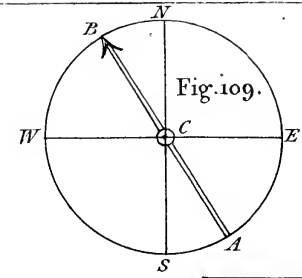
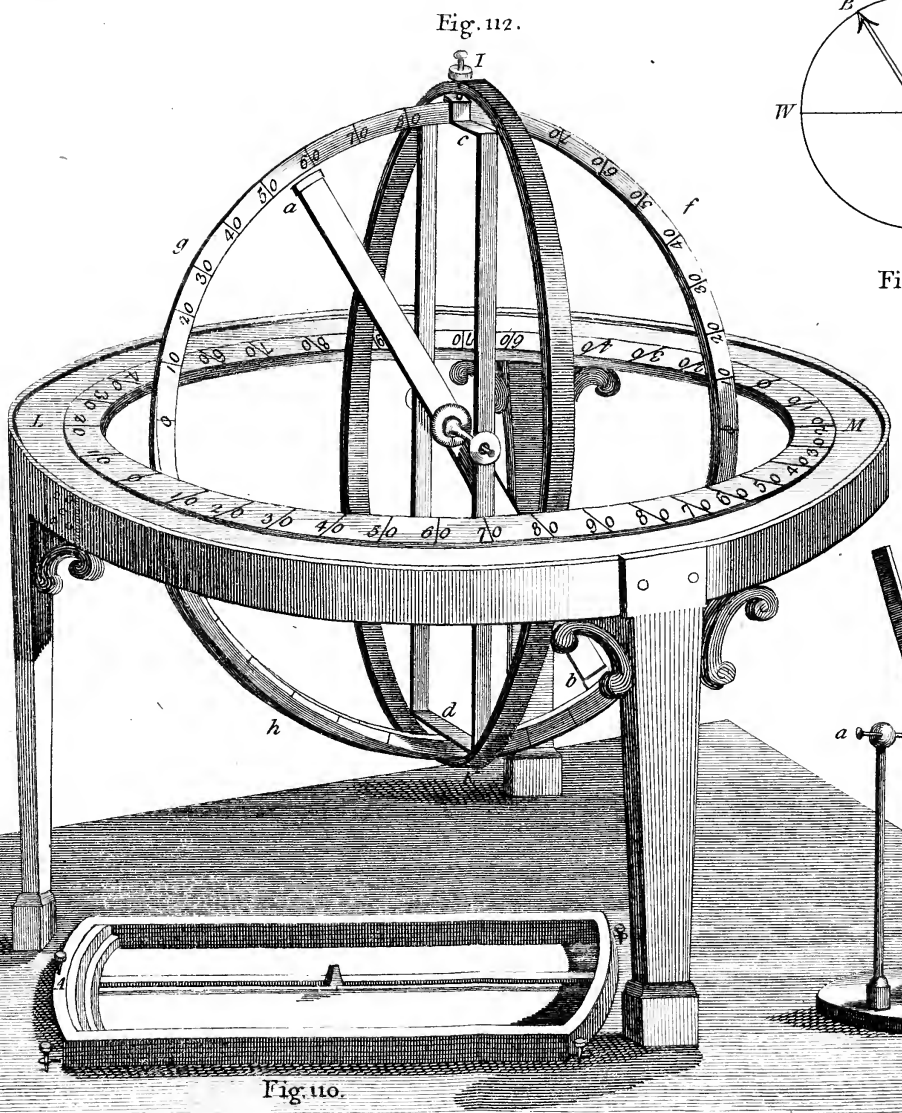
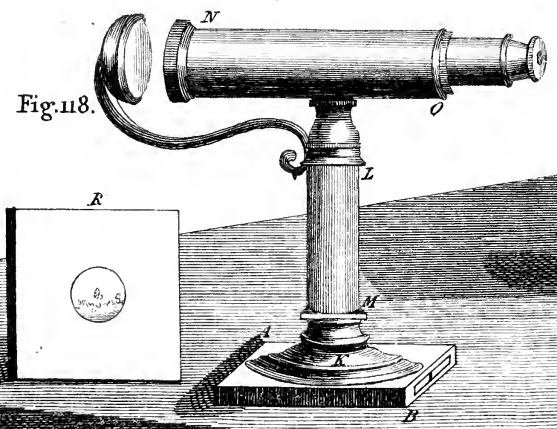
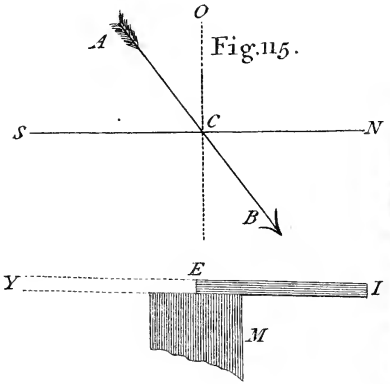
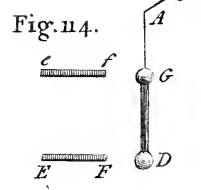
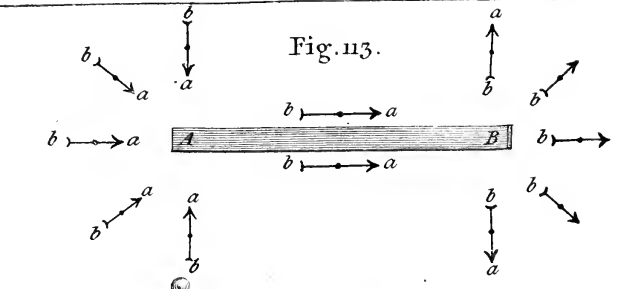


Fig. 105.











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