

PHILOSOPHICAL
TRANSACTIONS.

GIVING SOME

ACCOUNT

OF THE

Present Undertakings, Studies, and Labours

OF THE

INGENIOUS,

IN MANY

Considerable Parts of the WORLD.

VOL. XXXVII. For the Years 1731, 1732.

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when that River was frozen over for several Miles, and Booths and Streets were made on the Ice, an Ox roasted thereon, &c. For the lowest Point of Freezing in 1716, was on *January 7*, when the Spirits fell to 35 Degrees only of the Glafs I now make use: But the true Cause of the freezing of the *Thames* that Year was not barely the Excess of the Cold, but the long Continuance of it: Which was also the principal Cause of those remarkable Congelations of that River in 1683 and 1708, when I saw Coaches driven over the Ice, large Fires made on it, &c. I am, with great Respect,

Honoured S I R,

Uppinſter, Feb.
13th, 1737.

Yours,

WILLIAM DERHAM.

V. *A Letter to Cromwell Mortimer, M. D. Secr. R. S. containing ſeveral Experiments concerning Electricity; by Mr. Stephen Gray.*

S I R,

IN the Year 1729 I communicated to Dr. *Deſagu-liers*, and ſome other Gentlemen, a Diſcovery I had then lately made, ſhewing that the Electrick Vertue of a Glafs Tube may be conveyed to any other Bodies, ſo as to give them the ſame Property of attract-
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ing and repelling light Bodies, as the Tube does, when excited by rubbing; that this attractive Vertue might be carried to Bodies that were many Feet distant from the Tube. On *May* the 1st Dr *Desaguliers* made a Report of the Experiments he had seen, to the *Royal Society*; I then promised to communicate a more particular Account of these Experiments to the *Society*; but as I was the next Day to go into the Country, where I knew that I should have the Opportunity of carrying on the Experiments much farther than I had yet done, for want of Room in my Chamber, which was not large enough for carrying on several other Experiments I had in View; I was willing, as I had begun the Discovery, to carry it on as much farther as I could, before I communicated it to the *Royal Society*, which I now humbly offer to their Consideration.

In *February* 1723, I repeated some of the Experiments I had formerly made, in the first Discovery of an Electrical Attraction in many Bodies, not before known to have that Property, which I communicated to the *Royal Society*. An Account of those Experiments is given in the *Philosophical Transactions*, N^o 366. I made several Attempts on the Metals, to see whether they might not be made attractive by the same Method as other Bodies were, *viz.* by heating, rubbing and hammering, but without any Success: I then resolved to procure me a large Flint-Glass Tube, to see if I could make any farther Discovery with it, having called to Mind a Suspicion which some Years ago I had, that as the Tube communicated a Light to Bodies, when it was rubbed in the Dark, whether it might not at the same Time communicate an Electricity to them, though

I never till now tried the Experiment, not imagining the Tube could have so great and wonderful an Influence, as to cause them to attract with so much Force, or that the Attraction would be carried to such prodigious Distances, as will be found in the Sequel of this Discourse.

Before I proceed to the Experiments, it may be necessary to give a Description of the Tube: Its Length is three Feet five Inches, and near one Inch two Tenths in Diameter: I give the mean Dimensions, the Tube being larger at each End than in the Middle, the Bore about one Inch. To each End I fitted a Cork, to keep the Dust out when the Tube was not in use.

The first Experiment I made, was to see if I could find any Difference in its Attraction, when the Tube was stopped at both Ends by the Corks, or when left open, but could perceive no sensible Difference; but upon holding a Down-Feather over against the upper End of the Tube, I found that it would go to the Cork, being attracted and repelled by it, as by the Tube when it had been excited by rubbing. I then held the Feather over against the flat End of the Cork, which attracted and repelled many Times together; at which I was much surprized, and concluded that there was certainly an attractive Vertue communicated to the Cork by the excited Tube.

Having by me an Ivory Ball of about one Inch three Tenths Diameter, with a Hole through it, this I fixed upon a Fir-Stick about four Inches long, thrusting the other End into the Cork, and upon rubbing the Tube, found that the Ball attracted and repelled the Feather with more Vigour than the Cork had done,
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repeating its Attractions and Repulsions for many Times together: I then fixed the Ball on longer Sticks, first upon one of eight Inches, and afterwards upon one of twenty-four Inches long, and found the Effect the same. Then I made use of first Iron, and then Brass Wire, to fix the Ball on, inserting the other End of the Wire in the Cork, as before, and found that the Attraction was the same as when the Fir-Sticks were made use of, and that when the Feather was held over against any Part of the Wire, it was attracted by it; but though it was then nearer the Tube, yet its Attraction was not so strong as that of the Ball. When the Wire of two or three Feet long was used, its Vibrations, caused by rubbing the Tube, made it somewhat troublesome to be managed: This put me upon thinking, whether if the Ball was hung by a Packthread, and suspended by a Loop on the Tube, the Electricity would not be carried down the Line to the Ball: I found it to succeed accordingly; for upon suspending the Ball on the Tube by a Packthread about three Feet long, when the Tube had been excited by rubbing, the Ivory Ball attracted and repelled the Leaf-Brass, over which it was held, as freely as it had done, when it was suspended on Sticks or Wire; as did also a Ball of Cork, and another of Lead that weighed one Pound and a quarter.

After I had found that the several Bodies above-mentioned had an Electricity communicated to them, I then went on to see upon what other Bodies the Tube would have the same Effect, beginning with the Metals, suspending them on the Tube by the Method above-mentioned; first in small Pieces, as with a Guinea, a Shilling, a Half-penny, a Piece of Block-Tin,
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a Piece of Lead ; then with larger Quantities of Metal, suspending them on the Tube by Packthread. Here I made use of a Fire-Shovel, Tongs, and Iron Poker, a Copper Tea-Kettle, which succeeded the same, whether empty, or full of either cold or hot Water ; a Silver Pint Pot ; all which were strongly Electrical, attracting the Leaf-Brass to the Hight of several Inches. After I had found that the Metals were thus Electrical, I went on to make Trials on other Bodies, as Flint-Stone, Sand-Stone, Load-Stone, Bricks, Tiles, Chalk ; and then on several vegetable Substances, as well green as dry, and found that they had all of them an Electric Vertue communicated to them, either by being suspended on the Tube by a Line, or fixed on the End of it by the Method above-mentioned.

I next proceeded to try at what greater Distances the Electric Vertue might be carried, and having by me Part of a hollow walking Cane, which I suppose was Part of a Fishing-Rod, two Feet seven Inches long ; I cut the great End of it, to fit it into the Bore of the Tube, into which it went about five Inches ; then when the Cane was put into the End of the Tube, and this excited, the Cane drew the Leaf-Brass to the Hight of more than two Inches, as did also the Ivory Ball, when by a Cork and Stick it had been fixed to the End of the Cane. A solid Cane had the same Effect, when inserted in the Tube after the same Manner as the hollow one had been. I then took the two upper Joints of a large Fishing-Rod, the one of *Spanish* Cane, the other partly Wood and the upper End Whale-bone, which, together with the Tube, made a Length of more than fourteen Feet. Upon the lesser
End

End of the Whale-bone was fixed a Ball of Cork of about an Inch and quarter Diameter; then the great End of the Rod being inserted in the Tube, the Leaf-Brafs laid on the Table, and the Tube excited, the Ball attracted the Leaf-Brafs to the Hight of about three Inches by Estimation. With several Pieces of *Spanish Cane* and *Fir-Sticks* I afterwards made a Rod, which, together with the Tube, was somewhat more than eighteen Feet long, which was the greatest Length I could conveniently use in my Chamber, and found the Attraction very nearly, if not altogether as strong, as when the Ball was placed on shorter Rods. Thus far I proceeded before I went into the Country, which I did the 21 of *May*, 1729, taking with me several *Glass Canes*, and such other Materials I thought would be necessary, and could not well be procured there. I shall now give an Account of the Experiments I then made, some of which were made at *Norton-Court* near *Feverham* in *Kent*, at my honoured Friend's *John Godfrey's*, Esq; the other at *Otterden-Place*, at my honoured Friend's *Granvil Wheeler's*, Esq; a worthy Member of the *Royal Society*, with whom I have had the Honour to be lately acquainted. I shall set down each Experiment in the Order of the Time and Place they were made, as I find it in my Notes.

The first Experiment was made at *Norton-Court*, *May* 14th, 1729, between six and seven o'Clock in the Evening. Having provided a Rod of about twenty-four Feet, that consisted of a *Fir-Pole*, of *Cane*, and the Top of *Reed*, upon the End of which the Ball of Cork was placed, and the great End of the Rod put into the Tube about seven or eight Inches; then the
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Leaf-Brafs being laid down, and the Tube rubbed, the Ball attracted and repelled the Leaf-Brafs with Vigour ; so that it was not at all to be doubted, but with a longer Pole the Electricity would have been carried much farther.

May the 16th, I made a Rod thirty-two Feet long, including the Tube ; the bigger Part of it was a Fir-Staff about six Feet and a half long, the rest was of Cane, and Reed for the top Part of it. All Things being prepared, as before, the Effect was the same as in the last Experiment, only the Pole bending so much, and vibrating by rubbing the Tube, made it more troublesome to manage the Experiment. This put me upon making the following Experiments.

May the 19th, about six in the Morning, the Ivory Ball being suspended on the Tube, by a Line of Pack-thread twenty-six Feet long, which was the Hight, I stood at in the Balcony, from the Court where he stood, that held the Board with the Leaf-Brafs on it ; then the Tube being rubbed, attracted the Leaf-Brafs to the Hight of near two Inches, as he that assisted informed me. This was repeated with the Cork Ball with the same Success.

May the 31st, in the Morning, to a Pole of eighteen Feet there was tied a Line of thirty-four Feet in Length ; so that the Pole and Line together were fifty-two Feet. With the Pole and Tube I stood in the Balcony, the Assitant below in the Court, where he held the Board with the Leaf-Brafs on it ; then the Tube being excited as usual, the Electric Vertue passed from the Tube up the Pole, and down the Line to the Ivory Ball, which attracted the Leaf-Brafs, and as the Ball passed

passed over it in its Vibrations, the Leaf-Brafs would follow it, till it was carried off the Board: But these Experiments are difficult to make in the open Air, the least Wind that is stirring, carrying away the Leaf-Brafs.

Some Time after I made several Attempts to carry the Electrick Vertue in a Line horizontally, since I had not the Opportunity here of carrying it from greater Hights perpendicularly, but without Success, for want of then making use of proper Materials, as will appear from what follows. The first Method I made Trial of, was by making a Loop at each End of a Line, and hanging it on a Nail drove into a Beam, the other End hanging downwards, through the Loop at this End the Line with the Ivory Ball was put; the other End of this Line was by a Loop hung on the Tube; so that that Part of the Line next the Ball hung Perpendicular, the rest of the Line Horizontal: Then the Leaf-Brafs being laid under the Ball, and the Tube rubbed, yet not the least Sign of Attraction was perceived. Upon this I concluded, that when the Electrick Vertue came to the Loop that was suspended on the Beam, it went up the same to the Beam; so that none, or very little of it at least, came down to the Ball, which was afterwards verified, as will appear by the Experiments that will be mentioned hereafter. Upon this I gave over making any farther Attempts of carrying the Electricity horizontally, designing at my Return to *London*, if I could get Assistance, to have tried the Experiment from the Top of the Cupola of *St. Paul's*, not doubting but the Electrick Attraction would

would be carried down perpendicular, from thence to the Ground.

June the 30th, 1729, I went to *Otterden-Place*, to wait on Mr. *Wheler*, carrying with me a small solid Glass Cane of about eleven Inches long, and seven eighth Parts of an Inch in Diameter, with some other requisite Materials, designing only to give Mr. *Wheler* a Specimen of my Experiments. The first was from the Window in the Long Gallery that opened into the Hall, the Hight about sixteen Feet; the next from the Battlements of the House down into the fore Court, twenty-nine Feet; then from the Clock-Turret to the Ground, which was thirty-four Feet, this being the greatest Hight we could come at; and notwithstanding the Smallness of the Cane, the Leaf-Brass was attracted and repelled beyond what I expected. As we had no greater Hights here, Mr. *Wheler* was desirous to try whether we could not carry the Electric Vertue horizontally. I then told him of the Attempt I had made with that Design, but without Success, telling him the Method and Materials made use of, as mentioned above. He then proposed a Silk Line to support the Line, by which the Electric Vertue was to pass. I told him it might do better upon the Account of its Smallness; so that there would be less Vertue carried from the Line of Communication, with which, together with the apt Method Mr. *Wheler* contrived, and with the great Pains he took himself, and the Assistance of his Servants, we succeeded far beyond our Expectation.

The first Experiment was made in the matted Gallery July 2, 1729, about Ten in the Morning. About four Feet

Feet from the End of the Gallery there was a cross Line that was fixed by its Ends to each Side of the Gallery by two Nails; the middle Part of the Line was Silk, the rest at each End Packthread; then the Line to which the Ivory Ball was hung, and by which the Electric Vertue was to be conveyed to it from the Tube, being eighty Feet and a half in Length, was laid on the cross Silk Line, so as that the Ball hung about nine Feet below it: Then the other End of the Line was by a Loop suspended on the Glass Cane, and the Leaf-Brass held under the Ball on a Piece of white Paper; when the Tube being rubbed, the Ball attracted the Leaf-Brass, and kept it suspended on it for some Time.

This Experiment succeeding so well, and the Gallery not permitting us to go any farther in one Length, Mr. *Wheler* thought of another Expedient, by which we might encrease the Length of our Line, which was by putting up another cross Line near the other End of the Gallery; and over the Silk Part of both the Lines there was laid a Line that was long enough to be returned to the other End, where the Ball hung; and though now both Ends of the Line were at the same End of the Gallery, yet Care was taken that the Tube was far enough off from having any Influence upon the Leaf-Brass, except what passed by the Line of Communication: Then the Cane being rubbed, and the Leaf-Brass held under the Ivory Ball, the Electric Vertue passed by the Line of Communication to the other End of the Gallery, and returned back again to the Ivory Ball, which attracted the Leaf-Brass, and suspended it as before. The whole Length of the Line was 147 Feet.

We then thought of trying whether the Attraction would not be stronger without doubling or returning the Line, which we found Means of doing in the Barn, where we had a Line of 124 Feet long, fourteen Feet of which hung perpendicular from the Silk Line; and now the Attraction was, as we then concluded, stronger than when the Line was returned, as in the matted Gallery.

July 3, having now brought with me the great Glas Tube, between Ten and Eleven in the Morning we went again into the Barn, carrying with us the solid Cane, and repeated the last mentioned Experiment with both the Tube and Cane; but the Attraction was not so strong as in the preceding Evening, nor was there so great a Difference in the Attraction communicated by the solid Cane and Glas Tube, as one would have expected, considering the Difference of their Lengths and Diameters.

We then proceeded farther, by adding so much more Line as would make a Return to the other End of the Barn, the whole Length of the Line being now 293 Feet; and though the Line was so much lengthened, we found no perceivable Difference in the Attraction, the Ball attracting as strongly as before. This encouraged us to add another Return; but upon beginning to rub the Tube, our Silk Lines broke, being not strong enough to bear the Weight of the Line, when shaken by the Motion given it by rubbing the Tube. Upon this, having brought with me both Brass and Iron Wire, instead of the Silk we put up small Iron Wire; but this was too weak to bear the Weight of the Line. We then took Brass Wire of a somewhat larger Size than

than that of Iron. This supported our Line of Communication; but though the Tube was well rubbed, yet there was not the least Motion or Attraction given by the Ball, neither with the great Tube, which we made use of when we found the small solid Cane to be ineffectual: By which we were now convinced, that the Success we had before, depended upon the Lines that supported the Line of Communication, being Silk, and not upon their being small, as before Trial I imagined it might be; the same Effect happening here as it did when the Line that is to convey the Electric Vertue is supported by Packthread; *viz.* that when the Effluvia come to the Wire or Packthread that supports the Line, it passes by them to the Timber, to which each End of them is fixed, and so goes no farther forward in the Line that is to carry it to the Ivory Ball.

Finding that our Silk Threads were too weak to bear many Returns of Line, Mr. *Wheler* thought of another Way of managing them, so that fewer Returns might be upon each Silk Line; which was by placing two other cross Lines some Feet below the upper ones; so that every other Turn of Line was suspended by the lower cross Line. By this Means there was but half the Weight of Line upon each Silk, of what there was when only two cross Lines were made use of as before. By this Contrivance, we could add a much greater Length of Line, without Danger of breaking our Silk. We then put up a Line that was 666 Feet in Length, by eight Returns: Then the Leaf-Brafs being held on a Piece of white Paper under the Ivory Ball, and the Tube, with the other End of the Line suspended.

suspended on it; being rubbed for some Time, the Leaf-Brass was attracted as manifestly as it had been with much shorter Lines. We then repeated the Experiment with the little short solid Cane, and found there was somewhat of an Attraction, but not near so great as with the large Tube.

Though the going and returning of the Electric Effluvia was very surprizing, yet we were willing to try how far the attractive Vertue might be carried in a continued right Line; the Method of doing which was thus: That End of the Line where the Attraction was to be made, was suspended on a Silk Line that was fixed cross the Garret Window on the North-side of the House, which was by Estimation about forty Feet high; at about an hundred Feet from hence two Rods or Poles of about ten Feet long, and at two Feet distance from each other, were drove into the Ground, so as that they stood nearly perpendicular. These were in the great Garden. Beyond these, in the great Field, that is separated from the Garden by a deep Foss, about the same Distance from the first, were another Pair of Poles fixed; then four others at a like Distance. Upon the Ends of these Poles were tied the cross Lines of Silk, to support the Line of Communication, which being laid on the Silk Lines, the Ivory Ball hanging in the Garret Window, and the other End of the Line being hung by a Loop on the Tube, the Leaf-Brass was held under the Ball, and after the Tube had been rubbed for some Time, they called to me to let me know that there was an Attraction of the Leaf-Brass. This was several Times repeated with Success; then Mr. *Wheler* came into the Field, and rubbed the Tube himself,

himself, that I might see there was an Attraction; which I saw, though I perceived it not to be so strong, as when the Attraction was carried by a longer Line, by returning it, as in the Experiments above-mentioned. The Length of the Line was 650 Feet. This was several Times repeated, but the Experiment being made in the Evening, at length the Dew began to fall. We began about Seven o'Clock, or some little Time after, but before Eight the Attraction ceased: But whether this was caused by the Dew falling, or by my being very hot, we could not positively say, but I rather impute it to the latter. This Experiment was made July 14, 1729.

Note, That though we call the carrying the Electric Vertue by the Lines in this Position Horizontal, you are not to understand it in a strict Sense, as may be easily perceived by the Description of the Method; and That as the Line swagged down much below the Silk Lines that supported it, in the middle Part between those Lines, it was some Feet longer than the Distance of the Poles.

Some Days after this Experiment was repeated from the Turret Closet Window, when the Line was 765 Feet, and the Attraction was no less perceivable than in the Experiment above-mentioned.

More Experiments made at Mr. Wheeler's, shewing that large Surfaces may be impregnated with Electric Effluvia.

A large Map of the World, that had twenty-seven square Feet in it; a Table-Cloth containing fifty-nine square Feet; these suspended on the Tube by
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Packthreads, became Electrical. An Umbrello, suspended by a Packthread tied to the Handle of it, became strongly Electrical.

An Experiment proposed by Mr. Wheeler, to see whether the Electric Vertue would be any Way hindered by the magnetical Effluvia of a Loadstone.

This had a small Key hung by one of its arming Irons, and the Stone, together with the Key hung to it, were suspended on the Tube by a Packthread; then the Tube being rubbed, the Key and Stone both attracted the Leaf-Brass, the Attraction being the same as that of other Bodies.

An Experiment made to shew that the Electric Vertue is carried several Ways at the same Time, and may be conveyed to considerable Distances.

There was made three Stands, each composed of two upright Pieces of Fir, fixed perpendicular, near the Ends of a long square Board, distant from each other near a Foot and a half. Upon the Tops of these were tied Threads of Silk to support the Lines of Communication with the Tube and the attracting Bodies. One of these Stands was placed in the great Parlour, near the farther End; another in the little Parlour, and a third in the Hall, which was between the two Parlours: As the other two were one of them to the right, the other to the left Hand, this last was placed near the Hall-Window forwards; the two first were about fifty Feet, the other about twenty Feet from the Place where

where the Tube was held ; then there were taken three small square Pieces of Wood, that were tied to three Lines of Packthread : These were of about the Lengths above-mentioned. They were laid on the Silk Lines, and by Loops at the other Ends were suspended on the Tube ; then the Leaf-Brafs being held under the Pieces of Wood, and the Tube rubbed, they all of them attracted the Leaf-Brafs at the same Time. Some Time after, in my Absence, Mr. *Wheler* tried a red hot Poker, and found that the Attraction was the same as when cold. He also suspended a live Chick upon the Tube, by the Legs, and found that the Breast of the Chick was strongly Electrical.

At Mr. Godfrey's I made the following Experiments ; shewing that the Electric Vertue may be carried from the Tube, without touching the Line of Communication, by only being held near it.

The first of these Experiments was made the 5th of August, 1729. I shall here mention some of the most considerable ones ; but as I did not always set down the Day of the Month, some of them may not be related in the Order of Time they were made ; nor did I always mention the Length of the Lines, these not being thought to be absolutely necessary.

I took a Piece of a Hair-Line, such as Linnen-Cloaths are dried on, of about eleven Feet in Length ; which, by a Loop at the upper End of it, was suspended on a Nail, that was drove into one of the Rafters in the Garret, and had at its lower End

a leaden Weight of fourteen Pounds hung to it by an Iron Ring : then the Leaf-Brafs was laid under the Weight, and the Tube rubbed, and being held near the Line without touching it, the Lead-Weight attracted and repelled the Leaf-Brafs for several times together, to the Hight of at least three, if not four Inches. If the Tube was held three or four Feet above the Weight, there would be an Attraction ; but if it were held higher up, so as to be near the Rafter where the Weight was hung by the Hair-Line, there would be no Attraction.

An Experiment, shewing that the Electrick Vertue may be carried several Ways at the same Time, by a Line of Communication, without touching the said Line.

There were taken two Hair-Lines, of between four and five Feet long ; to each of these was tied a square Piece of Cork, by Packthread ; the Lines were suspended by Loops at their upper Ends, upon two Nails ; near the lower Ends there was tied to the Hair-Lines a Piece of Packthread, by which there was a Communication between the two Hair-Lines ; then the Leaf-Brafs laid under the Corks, the Tube being rubbed, and held near one of the Lines, both the Corks attracted ; but that which was farthest, much stronger than that, near which the Tube was held. About the Middle of the Line of Communication they both drew with equal Force.

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Some Time after, at Mr. Wheeler's, we made the following Experiment, in order to try whether the Electric Attraction be proportional to the Quantity of Matter in Bodies.

There were made two Cubes of Oak, of about six Inches Square, the one solid, the other hollow : These were suspended by two Hair-Lines, nearly after the same Manner as in the Experiment above-mentioned ; the Distance of the Cubes from each other, was by Estimation, about fourteen or fifteen Feet ; the Line of Communication being tied to each Hair-Line, and the Leaf-Brafs placed under the Cubes, the Tube was rubbed and held over the Middle of the Line, and as near as could be guessed, at equal Distances from the Cubes, when both of them attracted and repelled the Leaf-Brafs at the same Time, and to the same Height ; so that there seemed to be no more Attraction in the solid than in the hollow Cube ; yet I am apt to think that the Electric Effluvia pass through all the interior Parts of the solid Cube, though no Part but the Surface attracts ; for from several Experiments it appears, that if any other Body touches that which attracts, its Attraction ceases till that Body be removed, and the other be again excited by the Tube.

A Continuation of the Experiments made at Mr. Godfrey's.

I next went on with an Experiment, to see if the Electric Vertue might not be conveyed to a Rod, without inserting it into the Bore of the Tube, or without touching the Rod, which I found to succeed,

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by suspending the Rod either by Lines of Silk, or by Pieces of Horse-Hair Fishing-Lines, placing a Ball of Cork on the lesser End of the Rod.

August 13, I took a large Pole that was twenty-seven Feet long, two Inches and a half Diameter at the great End, and at the lesser about half an Inch: It was that Sort of Wood they call Horse-Beech, with the Rind on. This was suspended by two Hair-Lines of about four Feet and a half in Length; the first Line was about two Feet from the great End of the Pole, the other about eight Feet from the lesser End; so that the Pole hung horizontal. At the little End of the Pole was hung a Ball of Cork about an Inch and a half Diameter by a Packthread about a Foot long, and a small leaden Ball upon the Cork to keep the Packthread extended: Then the Leaf-Brafs being laid under the Cork, the Tube rubbed and held near the great End of the Pole, the Cork Ball drew the Leaf-Brafs strongly to the Hight of an Inch, if not more: Then the Leaf-Brafs being held under several Parts of the Pole, it was attracted by it, as Mr. *Godfrey* observed, but not near so strongly as the Cork did.

About the Beginning of September I made the following Experiment, which shews that the Electric Effluvia will be carried in a Circle, and be communicated from one Circle to another.

There was taken a Hoop of about two Feet two Inches Diameter; this I suspended by a Hair-Line upon a Nail drove into a Beam; the Line was about four Feet long; then the Leaf-Brafs being laid under the Hoop, the Tube was rubbed, and held
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within the Hoop, near the upper Side of it, without touching it by several Inches: Then the lower Part of the Hoop attracted and repelled the Leaf-Brafs strongly; but when held near the lower Part, there was very little, if any Attraction. If the Tube was held near the outside of the Hoop, it attracted; but strongest, when at the same Time it was held near the Knot of the Hair-Line the Hoop was suspended by. To this Hoop there was tied a lesser Hoop of about a Foot and a half Diameter: It was tied to it by Packthread, so as to hang below it about two Inches; they were suspended together by the Hair-Line; then the Leaf-Brafs and the Tube being prepared, as hath been mentioned before, the Tube being held near the upper Hoop, the lower Part of the lower Hoop attracted strongly, and when held near the upper Part of the lower Hoop, but very weakly; but when held near the lower Part of the lower Hoop, there was no Attraction.

On the 15th of September I made the following Experiment, which shews, that the Electrick Effluvia have the same Effect in a Circle, when its Position is horizontal.

I took a large Hoop, of somewhat more than three Feet Diameter, and Breadth of about two Inches and a half; to this was tied at near equal Distances, four Lines: They were what they call Twine, which is of three Threads of Packthread twisted together, each about two Feet eight Inches long. These were tied with their Ends together to a Hair-Line of about two Feet and a half long, by which the Hoop was hung

hung on a Nail, as in the other Experiments, so that the Hoop hung now in an horizontal Position: Then the Leaf-Brafs being laid under the Edge of the Hoop, at between two and three Inches below it, the Tube being rubbed, and held between the Cords without touching them, the Leaf-Brafs was attracted and repelled for several times together; but when held near the outside of the Hoop, opposite to that Part where the Leaf-Brafs lay, the Attraction was much stronger.

About the latter End of Autumn, and the Beginning of the Winter in 1729, I resumed my Enquiry after other Electrick Bodies, to see what Addition I could make to the Catalogue of those mentioned above, in Pages 21, 22, and found many more that have the same Property, and may be excited to attract by the same Method. As for Instance, the dry withered Leaves of Reeds and Flags, Grass and Corn, both Leaves and Straw; the Leaves of Trees, as those of the Laurel, the Oak, the Walnut, the Chesnut, Hazle-nut, Apple and Pear-tree Leaves; so that we may conclude, that the Leaves of all Vegetables have this Attractive Vertue.

I shall now give an Account of the Experiments made at my Chamber in the Year 1730.

March the 23d, I dissolved Soap in the Thames-Water, then I suspended a Tobacco-Pipe by a Hair-Line, so as that it hung nearly horizontal, with the Mouth of the Bowl downwards; then having dipped it in the Soap-Liquor, and blown a Bubble, the Leaf-Brafs laid on a Stand under it, the Tube being rubbed, the Brafs was attracted by the Bubble, when the

the Tube was held near the Hair-Line. Then I repeated the Experiment with another Bubble, holding the Tube near the little End of the Pipe, and the Attraction was now much greater, the Leaf-Brafs being attracted to the Hight of near two Inches.

March the 25th, I repeated this Experiment after a somewhat different Manner: The Pipe was now suspended by two Lines of white sewing Silk, of about five Feet and a half long; these were hung upon two Nails drove into the Beam of my Chamber, distant from each other about a Foot, by Loops at the other End of the Lines, by which the Pipe was suspended; then the Bubble being blown, by holding the Tube to the little End of the Pipe, the Bubble attracted the Leaf-Brafs to the Hight of near four Inches. This Experiment was made to see whether fluid Bodies would not have an Electricity communicated to them.

April 8, 1730, I made the following Experiment on a Boy between eight and nine Years of Age. His Weight, with his Cloaths on, was forty-seven Pounds ten Ounces. I suspended him in a horizontal Position, by two Hair-Lines, such as Cloaths are dried on: They were about thirteen Feet long, with Loops at each End. There was drove into the Beam of my Chamber, which was a Foot thick, a Pair of Hooks opposite to each other, and two Feet from these another Pair in the same manner. Upon these Hooks the Lines were hung by their Loops, so as to be in the Manner of two Swings, the lower Parts hanging within about two Feet of the Floor of the Room: Then the Boy was laid on these Lines with his Face downwards, one of the Lines being put under his Breast, the other under

under his Thighs : Then the Leaf-Brafs was laid on a Stand, which was a round Board of a Foot Diameter, with white Paper pafte on it, fupported on a Pedestal of a Foot in Hight, which I often made ufe of in other Experiments, though not till now mentioned : Upon the Tube's being rubbed, and held near his Feet, without touching them, the Leaf-Brafs was attracted by the Boy's Face with much Vigour, fo as to rife to the Hight of eight, and fometimes ten Inches. I put a great many Pieces on the Board together, and almoft all of them came up together at the fame Time. Then the Boy was laid with his Face upwards, and the hind Part of his Head, which had fhort Hair on, attracted, but not at quite fo great a Hight as his Face did. Then the Leaf-Brafs was placéd under his Feet, his Shoes and Stockings being on, and the Tube held near his Head, his Feet attracted, but not altogether at fo great a Hight as his Head : Then the Leaf-Brafs was again laid under his Head, and the Tube held over it, but there was then no Attraction, nor was there any when the Leaf-Brafs was laid under his Feet, and the Tube held over them.

April the 16th, I repeated the Experiment with the Boy, but now the Attraction was not quite fo ftrong as at the firft, the Brafs not rifing higher than to about fix Inches. His Hands being fretched nearly horizontal, I placed a fmall Stand with Leaf-Brafs under each Hand, and under his Face the great one, furnifhed as the others ; when the excited Tube being held near his Feet, there was an Attraction by his Hands and Face at the fame Time. I then gave him the Top of a Fishing-Rod to hold in his Hand ; there was a
Ball

Ball of Cork stuck on the little End of it, under which the Leaf-Brafs being laid, and the Tube rubbed and held near his Feet, the Ball attracted the Leaf-Brafs to the Hight of two Inches, and repelled it, and attracted for several Times together with great Vigour.

April 21, I again repeated the Experiment on the Boy; and now he attracted much stronger than at the first: The Leaf-Brafs rose to his Face at the Hight of more than twelve Inches. Then I gave the Boy to hold in each Hand the Tops of two Fishing-Rods, with a Ball of Cork on each of their lesser Ends; then a small Stand being set under each Ball, with the Leaf-Brafs on it, the Tube being rubbed, and held near his Feet, both the Corks attracted and repelled together strongly. The Length of the Poles were each of them about seven Feet. Then the Boy was laid on his left Side, and a Fishing-Rod, of near twelve Feet in Length, given him to hold with both his Hands; there was a small Ball of Cork at the End of the Rod, that was an Inch and three quarters Diameter: Then all Things being prepared, the Tube held near the Boy's Feet, the Cork Ball attracted and repelled the Leaf-Brafs with Force to the Hight of at least two Inches.

Note, That when I speak of holding the Tube near the Boy's Feet, I mean over against the Soles of his Feet; and when near his Head, is to be understood the Crown of his Head; for when the Tube is held above, or over his Legs, the Attraction is not so strongly communicated to the other Parts of his Body.

By these Experiments we see that Animals receive a greater Quantity of Electrick Effluvia, and that they may be conveyed from them several Ways at the same Time to considerable Distances, wherever they meet with a Passage proper for their Conveyance, and there exert their Attracting Power.

In these Experiments, besides the large Stand above-mentioned, I made use of two small ones, which, as I found them very useful, it may not be improper to describe them. The Tops of them were three Inches Diameter ; they were supported by a Column of about a Foot in Hight, their Bases of about four Inches and a half : They were turned of *Lignum vitæ* ; their Tops and Bases made to skrew on for Convenience of Carriage. Upon the Tops were pasted white Paper. When the Leaf-Brafs is laid on any of these Stands, I find it is attracted to a much greater Hight than when laid on a Table, and at least three Times higher than when laid on the Floor of a Room.

June 20, I made the following Experiment, shewing that the Attraction and Repulsion is as strong, if not stronger, and that the Effluvia may be carried to great Lengths, without touching the Line by the Tube.

There was taken a Line of Packthread 231 Feet in Length ; it was supported on two cross Lines of blue Silk ; the Distance of these Lines was near eighteen Feet. About four Feet below one of these Lines, was put up another Silk Line of the same Colour : To this was tied one End of the Packthread ; at the other End the Ivory Ball hung ; the Line was returned over the

the cross Lines thirteen times ; then the Leaf-Brafs being laid under the Ball, upon one of the small Stands, and the Tube excited, the Ball attracted and repelled to the Hight of one of its Diameters, which was about an Inch and a quarter.

I have, by several Trials lately made, found that rubbing the Tube, and putting it up between the Returns of the Line in several Places, before I go with the Tube to the End of the Line, much facilitates, and causes the Attraction much sooner than when one stands with the Tube and applies it to the End of the Line only.

About the middle of July I went into the Country, and August 1, at Mr. Wheler's, we made the following Experiment; being an Attempt to see how far the Electric Vertue might be carried forward in a Line, without touching the same.

This Experiment was made by carrying the Line out of the Great Parlour Window into the Garden, and down the great Field before it. The Line was supported by fifteen Pair of Poles ; each Pair had a Line of blue Silk tied from one Pole to the other, the Length of about four Feet, equal to the Distance of the two Poles: About ten Feet from the Window there was a Silk Line put up cross the Room, upon which that Part of the Line hung that had the Ivory Ball upon it. Below the cross Line of the farthest Pair of Poles was placed another cross Line, four Feet from the Ground, to which was fastened the other End of the communicating Line, as mentioned in the Experiment above: Then the Leaf-Brafs and Tube being pre-

pared as usual, the Tube being held over the Line at several Distances, beginning towards that End where the Ball hung, and so proceeding towards the farther End of the Line, the Leaf-Brafs was attracted at the Stations not exceeding two or three hundred Feet, pretty strongly; but still grew weaker as we came towards the farther End of the Line: Yet even at the End of the Line the Leaf-Brafs would be lifted by the Ball, when the Tube touched the Line, whose Length was 886 Feet.

I should now have given some Account of the Discovery I made the last Year concerning the Attraction of coloured Bodies, shewing that they attract more or less, according to what Colours they are of, though the Substance be the same, and of equal Weight and Bigness; only I shall observe, that I find the Red, Orange or Yellow, attract at least three or four times stronger than Green, Blue or Purple: But having very lately found out a new and more accurate Method of making these Experiments, I must beg Leave to proceed farther with them, before I communicate them. I am,

S I R,

Charter-House,
Feb. 8, 1734.

Your Humble Servant,

STEPHEN GRAY.

VI. Cur-

IV. *A Letter from Mr. Stephen Gray to Dr. Mortimer, Secr. R. S. containing a farther Account of his Experiments concerning Electricity.*

Charter-House, June 7th, 1732.

S I R,

SINCE my last (N^o 422) wherein I gave an Account of my Experiments, shewing Water will be attracted by Electrick Bodies, and that it may have an Electrick Vertue communicated to it, so as to attract solid ones, I have been upon another Enquiry; Whether there might not be a Way found to make this Property of Electrical Attraction more permanent in Bodies? How far I have succeeded in this Attempt, will appear by the Experiments I have made on the several Bodies mentioned in the following Catalogue; and as they were all of them prepared after the same manner, excepting Numb. 18 and 19, which shall be described afterwards, a general Description of the Method of preparing and preserving them in a State of Attraction, may suffice.

The Bodies on which the Experiments were made, were Rosin both black and white, Stone-Pitch, Shell or Gum-Lac, Bees-Wax, and Sulphur. I procured three Iron Ladles of several Sizes, in which I melted these Substances, making use of that which I thought most convenient for the Quantity I designed to melt. When any of these Bodies were melted, they were

P p

taken

taken off the Fire, and set by in the Ladle to cool and harden; then it was returned to the Fire, where it remained till it was melted about the Bottom and Sides of the Ladle, so as to be moveable; so that by inverting the Ladle, it might be taken out; having the Form of nearly the Section of a Sphere, the Convex Surface, as also the Plain one, being naturally (if I may so say) polished, excepting the Sulphur, which cools without retaining its Polish, except when cast in Glass Vessels, as shall be shewed hereafter. I shall now proceed to the Experiments and Observations made on these Electric Bodies.

When any of them were taken out of the Ladle, and their Convex Surface hardened, they would not at first attract, till the Heat was abated, or till they came to a certain Degree of Warmth, and then there was a small Attraction; which Warmth I estimated to be nearly that of a Hen's Egg when just laid. The Attraction encreasing so, as when cold, to attract at least ten times farther than at first.

The manner of preserving them in a State of Attraction, was by wrapping them up in any thing that would keep them from the external Air; as at first for the smaller Bodies I used white Paper, but for the larger ones white Flannel; but afterwards found that black Worsted Stockings would do as well. Being thus clothed, they were put into a large Fir Box, there to remain, till I had Occasion to make use of them.

The Cylinder of Sulphur, Numb. 18, was made by melting the Sulphur, and pouring it into a Cylindrick Glass Vessel, which had first been heated, to prevent its cracking. When the Sulphur was hardened, it

was

was somewhat less than the Glass; so that by inverting the Glass, it came out easily, and had a polished Surface almost as smooth as the Glass in which it was cast. The large Cone of Sulphur, Numb. 19, was made after the same manner; *viz.* by being cast in a large Drinking-Glass.

I am now to give an Account of the Observations made on the several Bodies mentioned in the Catalogue, but must first give a Description of the Catalogue. The first Column contains the Number, which in a small Piece of Paper is fixed on each of the several Bodies; the Name of which is given in the second Column, whether they are single or compound Substances. The third Column shews of what Weight they were of when melted, in Ounces and Drachms of *Averdupois* Weight. In the fourth Column you have the Days of the Month when the Body was melted and received its Form, and consequently when it first began to attract.

I did for thirty Days continue to observe every one of these Bodies, and found that at the End of the said Time they attracted as vigorously as at the first or second Day, as they do now at the writing hereof. By the Times mentioned in the Catalogue, being subtracted from any Time after, will be shewn how long any of the Bodies have continued their Attractive Vertue; by which it will appear, that some of them have not lost their Attraction for more than four Months: So that we have some Reason to believe, that we have now discovered that there is a *perpetual attractive Power* in all Electric Bodies, without exciting by either rubbing, beating, &c. or any other Attrition. But this will further appear by the Account I am now to give of the two

last Bodies mentioned in the Catalogue. The Cone of Sulphur, Numb. 19, that was cast in a large Drinking-Glass, in about two Hours after it was taken out of the Glass, attracted, and the Glass attracted too, but at a small Distance. Next Day the Sulphur was taken out of the Glass, and then it attracted strongly, but there was now no perceivable Attraction of the Glass. Then the Cone of Sulphur was set with its Base upon the Lid of the Fir Box, wherein the other Electric Bodies lay, and the Glass whelmed over it. I examined it every Day after, and still found it to attract; but finding the Place not so convenient, having Occasion to look into the Box often, I removed it to the Table that stands between the two Windows of my Chamber, where it has continued to this Time, and whenever the Glass is taken off, attracts at near as great a Distance as the Sulphur that is clothed and shut up in the Box abovementioned. And though at first there was no Attraction, when the Glass was taken off, yet I now find, that in fair Weather the Glass also attracts, but not at so great a Distance as the Sulphur, which never fails to attract, let the Wind or Weather be never so variable, as do all the other Bodies mentioned in the Catalogue; only in wet Weather the Attractions are not made at so great a Distance as in fair Weather.

Number 20 is a Cake of Sulphur that was melted; and as the other Bodies have taken the Form of a Convex Section of a Sphere, this, when cold, was laid with its flat Side downwards, on the same Table with the Cone of Sulphur: They were both placed so near the Wall, as to prevent the Sun shining on them. This was, as the Catalogue shews, on the 18th of
of

of *April*; and though it had no manner of Clothing or Covering, has attracted ever since. And in this, as in the other Bodies, the Attraction will be according to the Weather; but when it attracts the strongest, it is not more than the tenth Part of what the Cone of Sulphur, that is covered, attracts.

The manner of observing these Attractions is best performed by holding the Attracting Body in one Hand, and a fine white Thread tied to the End of a Stick, in the other; by this means far less Degrees of Attraction will be perceived, than by making use of Leaf-Brass. When the Thread is held at the utmost Distance, it may be attracted; the Motion of it is at first very slow, but still accelerating as it approaches nearer to the attracting Body.

I am now on the Subject of permanent Attraction in Glafs, then in the other Bodies, but have not yet completed those Experiments, meeting with more Interruption by the Weather.

With a small Hand Air-Pump that was lent me by a Friend, I have made Experiments on several Bodies, and find that they will attract *in vacuo*, and that at very nearly the same Distance as *in pleno*, provided that the Experiment be made in the same Receiver filled with Air; as will appear by the following Experiments.

There was taken a hollow Glafs Sphere, of somewhat more than $2\frac{1}{2}$ Inches Diameter, being first excited. It was suspended by a Loop of Silk that went through a small Cork, with which the Hole in the Glafs Ball, by which it was blown, was stopped, and by the Loop suspended on a small Hook that was screwed on to the Brass Wire that came through the

the Collar of Leather in the Brass-Plate that covered the Top of the open Receiver ; as in the Experiment of letting fall the Guinea and Feather *in vacuo*. Then the Ball was drawn up to the Top of the Receiver, and the Top of the small Stand, covered with Paper, was laid on the wet Leather, on the Plate of the Pump, and Leaf-Brass laid on the same. Then the Air was exhausted, when the Glass Ball was let down to about an Inch, or somewhat more, towards the Pieces of Leaf-Brass : Many of them were attracted by it. Then the Air was let into the Receiver, and the Leaf-Brass laid on the Stand, the Ball being, as before, suspended, was let down to about the same Distance from the Leaf-Brass as before, and there seemed to be very little Difference in the Attraction.

I have made the same Experiments with Sulphur, Shell-Lac, Rosin, and white Bees-Wax. These would be attracted to the Height of an Inch and a half by Estimation ; and when the Experiment was made with the Receiver full of Air, there was very little, if any Difference in the Height of the Attraction, when there was the same Time spent before the Attraction was begun *in pleno*, as there was required to exhaust the Receiver.

A CATALOGUE of the several Electric Bodies mentioned in the foregoing Discourse.

N ^o .	Names of the several Bodies.	Weight.	Month.	Days.
		3	3	
1	Fine black Rosin — —	2	0	January 31
2	Stone Pitch and black Rosin	2	2	January 31
3	Fine Rosin and Bees-Wax	2	1	February 1
4	Stone Pitch — —	1	7	February 1
5	Stone Sulphur — —	3	6	February 4
6	Shell-lac — —	10	0	February 10
7	Fine black Rosin — —	10	4	February 11
8	Bees-Wax and Rosin — —	9	0	February 12
9	Rosin 4, and Gum-lac 1 part	10	0	February 12
10	Sulphur — —	18	0	February 15
11	Stone Pitch — —	10	12	February 16
12	Black Rosin — —	13	9	February 23
13	White Rosin — —	7	12	February 25
14	Gum-lac — —	11	14	February 26
15	Gum-lac and black Rosin ana	9	12	February 26
16	Gum-lac 4 parts, Rosin 1 pt.	17	8	February 28
17	Shell-lac, fine black Rosin ana	28	4	March 2
18	A Cylinder of Stone Sulphur	19	4	March 20
19	A large Cone of Stone Sulphur	30	0	March 29
20	A Cake of Sulphur — —	11	4	April 29

S I R,

Be pleased to communicate these to the *Royal Society*, to whom I hope they will be no less acceptable than some of my former Discoveries from me, who am,

S I R,

Theirs, and your most Obedient Servant,

Stephen Gray.

Philosophical transactions of the Royal society of London : giving some accompt of the present undertakings, studies, and labours of the ingenious in many considerable parts of the world

AN

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H. *A Letter concerning the Electricity of Water, from Mr. Stephen Gray to Cromwell Mortimer, M. D. Secr. R. S.*

S I R,

THE Approbation the former Communication of my Electrical Experiments (*Transact. Numb. 417.*) to the *Royal Society* did meet with, by their most generous Encouragement, hath been a great Inducement to me to go on with them, to see what farther Discoveries I can make upon the Subject of this Species of Attraction. I shall at present communicate only two Experiments; the first shewing that Water may have an Attractive Vertue communicated to it from an Electric Body; the other, that Water is not only attracted by the Tube, or any other absolutely Electric Body, but that this Attraction is attended with several remarkable Circumstances.

I. In the former Account of my Experiments, I described the manner of communicating an Attraction to a Bubble of soaped Water; but I have now found, that even *a Body of Water receives an Attractive Vertue, and also a Repelling one, by applying the excited Tube near it, after the same manner as solid Bodies do.* To perform this Experiment, I caused a wooden Dish to be turned, with a Screw-hole at the Bottom, but not so far as to come through the Wood: This was screwed on to the upper End of one of the Stands I have mentioned in the other Experiments, the other Top being taken off: The Dish was about
four

four Inches Diameter, and one Inch deep. Then the Stand was set on a Cake of Rosin, or a Plate of Glass, or the Brims of a Drinking-Glass, or of a Cylindrick one, such as are used for Water Glasses. The Glass must be first warmed, then the Dish being filled with Water, the Tube rubbed, and moved both under the Dish and over the Water three or four times, without touching them. After it has been excited, not only the Dish, but the Water also, becomes Electrical; and if a small Piece of Thread, or a narrow Slip of thin Paper, or a Piece of Sheet-Brass, commonly called Tinsel, be held over the Water in an horizontal Position, within about an Inch or some times more, any of the said Bodies will be attracted to the Surface of the Water, and be repelled, but not so often as by Solids. If a pendulous Thread be held at some Distance from the outside of the Dish, it will be attracted and repelled by it many times together with a very quick Motion, but not at so great a Distance as when the Dish is empty.

II. *An Experiment shewing, that Water is attracted by the Tube, and that the Attraction is attended with several remarkable and surprising Phenomena.*

This Experiment being to be made with small Quantities of Water, I at first made use of some of the Brass Concave little Dishes in which I formerly ground Microscopes; but have since caused to be made a more convenient Apparatus, which consists of a small Pedestal of about four Inches and a half long, the Base of Ivory about two Inches Diameter. Upon the upper End, as in the larger Stand, there is a Screw, upon

on which is screwed on one of the little Dishes, which are made of Ivory: Of these I have several Sizes, from three Quarters to one Tenth of an Inch Diameter. When any one of these little Vessels is filled with Water, so as that it may stand above the Brims of the Cup, and has acquired a Spherical Surface (as it will do in the smallest Cups) let it be set on the Table with the little Stand to which it had before been screwed, or, which is better, upon the larger Stand mentioned above; the great Dish being taken off, and the small plain Top screwed on; being thus prepared, let the Tube be excited, and held over the Water at the Distance of about an Inch or more. If it be a large Tube, there will first arise a little Mountain of Water from the Top of the Drop, of a conical Form, from the Vertex of which there proceeds a Light (very visible when the Experiment is performed in a dark Room) and a snapping Noise, almost like that when the Fingers are held near the Tube, but not quite so loud, and of a more flat Sound: Upon this immediately the Mountain, if I may so call it, falls into the rest of the Water, and puts it into a tremulous and waving Motion. I have now a few Days since repeated this Experiment in the Day-time, where the Sun shined: I perceived that there were small Particles of Water thrown out of the Top of the Mount, and that sometimes there would arise a very fine Stream of Water from the Vertex of the Cone, in the manner of a Fountain, from which there issued a fine Steam, or Vapour, whose Particles were so small as not to be seen; yet it is certain that it must be so, since the under Side of the Tube was wet, as I found when I came to rub the Tube again; and I have since found, that though there does not
always

always arise that Cylinder of Water, yet there is always a Steam of invisible Particles thrown on the Tube, and sometimes to that Degree as to be visible on it. When some of the larger Cups are made use of, they are to be filled as high as may be without running over: The Surface will be flat about the middle Part, but when the Tube is held over it, the middle Part will be depressed into a Concave, and the Parts towards the Edge be raised; and when the Tube is held over against the Side of the Water, the little conical Protuberance of Water issues out with its Axis horizontally, and after the crackling Noise, returns to the rest of the Water, and sometimes there will be thrown out of it small Particles of the same, as from the smaller Portions of Water above mentioned. I am,

S I R,

The Society's, and Your most

Charter-House,
Jan. 20, 1733 $\frac{1}{2}$.

Obedient Servant,

STEPHEN GRAY.

III. A

PHILOSOPHICAL
TRANSACTIONS.

GIVING SOME

ACCOUNT

OF THE

Present Undertakings, Studies, and Labours,

OF THE

INGENIOUS,

IN MANY

Considerable Parts of the WORLD.

VOL. XXXIX. For the Years 1735, 1736.

L O N D O N :

Printed for T. WOODWARD, at the *Half-Moon*, between
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M.DCC.XXXVIII.

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of the Times will be discovered, which will serve for ever afterwards as a Rule to adjust the Observations.

The only View that I have in communicating this Paper, and in computing the Eclipses for Time to come, is to encourage those Persons, who will find their Advantage in it, to make Use of this Help for obtaining the Longitude at Sea, till better Methods are offered.

V Experiments and Observations upon the Light that is produced by communicating Electrical Attraction to animal or inanimate Bodies, together with some of its most surprising Effects; communicated in a Letter from Mr. Stephen Gray, F. R. S. to Cromwell Mortimer, M. D. R. S. Secr.

S I R,

Charter-House, Jan. 28th, 1734-5.

IT is now some Months ago that I promised to give the *Society* an Account of what Experiments I had then made; but soon after there occur'd to my Thoughts several others, which I was willing to try the Success of; which Experiments requiring an Addition to the *Apparatus*, that I might make them more compleat, I hope will be a sufficient Apology for this Delay.

I see you have published Mr. *Dufay's* Letter to the Duke of *Richmond*, in the *Philosophical Transactions*,

actions, No 431. 'tis no small Satisfaction to me, that my Electrical Discoveries have not only been confirmed by so judicious a Philosopher as Mr. *Dufay*; but that he has made several new ones of his own, more especially that important luciferous one, which put me upon making the Experiments I am now going to relate.

I shall first give some Account of the Experiments made the last *Spring*, soon after I received the Translation of Mr. *Dufay's* Letter; then of those we made at my honoured Friend's, *Granvill Wheeler*, Esq; F.R.S. in the Months of *July* and *August*; and lastly proceed to those I have made since my Return to *London*, which was in *September* last.

As I had not any silk Lines by me strong enough to bear the Boy, I caused him to stand on some of the Electric Bodies; and, as I concluded, found the Effect the same as mentioned by Mr. *Dufay*. I shall not need to mention the Particulars of the Experiment, but proceed to those that were suggested to me upon Mr. *Dufay's* saying, that these Snappings or Sparks are not excited, if a Piece of Wood, or any other Substance than a living Body, be passed over the Person suspended on the Lines, unless it be a Piece of Metal: From thence I concluded, that if I suspended the Metal upon silk Lines, or laid it upon any of the Electric Bodies, the Effect must be the same, when the Metal had been made Electrical by the Tube, and the Hand of any one was held near it, and found it succeeded accordingly. I began first with some common Utensils that were at Hand, such as the Iron Poker, Tongs, and Fire Shovel; any of these being suspended upon Lines of the largest sewing Silk then

the excited Tube, being applied first to the Knob of the Poker, and after it the Hand, there was the Snap and Pricking felt, as I expected; and the Effect was the same, when the Tube was first applied to the other End of the Poker. I had by me a three pronged Iron Instrument, which was made many Years ago; its Use was designed for propping up the Observatory Table, when I observed the Spots in the Sun; the Prongs were about half an Inch Diameter, two of them about 22 Inches, and the third about 8 Inches long; they were tapering towards the Ends, and pointed: this being laid either upon Cylinders of Glass, Cakes of Rosin and Bees Wax, or on a Cake of Sulphur, the Tube being applied to the End of any of the Legs, the Hand or Cheek being applied near the other, both the other Legs had the same Effect as that to which the Tube had been applied; but by holding my Cheek near any of the Points of the Legs, the pricking or burning Pain was much more sensibly felt, and was sometimes felt for several Minutes after. I was not so inquisitive at that Time about making the Experiment in the Dark, that I might see the Light proceeding from the Iron, not thinking the Electricity communicated to the Metals would have produced so surprising Phenomena, as by the following Account of the Experiments will be described.

1. I come now to give some Account of the Experiments we made at Mr. *Wheler's*, beginning first with the Success we had in repeating Mr. *Dufay's* Experiment. Mr. *Wheler*, soon after my coming to him, procured silk Lines strong enough to bear the Weight of his Footboy, a good stout Lad; then having suspended him upon the Lines, the Tube being applied

applied to his Feet or Hands, and the Finger of any one that stood by held near his Hands or Face, he found himself pricked or burnt, as it were by a Spark of Fire, as Mr. *Dufay* had related, and the snapping Noise was heard at the same Time; but it did not succeed with us, when we applied our Hands to any part of his Body through his Cloaths, except upon his Legs, upon which he felt the Pain through his Stockings, although they were very thick ones.

2. Being desirous to make the Experiment upon another Species of Animals, we took a large white Cock, and suspended him upon the Lines first alive, and the Effect was the same as on the Boy, whether we applied our Fingers to any Part of his Body, or our Check to his Beak, Comb or Claws; then the Cock was killed, and put on the Lines again, and we found very little, if any, Difference, from the Effect it had on us when the Cock was living: We then caused the Cock to be stripped of his Feathers, and the Difference from what has been said before was not very great.

3. We took a large Sirloin of Beef, that came from an Ox that had been killed two Days before, and suspended it on the silk Lines; then the Fingers held near any Part of it, there was a Snapping, and the Fingers were pushed or pricked; but the Snapping was thought not to be quite so loud as when the Experiment was made on the Cock.

4. We caused to be made an Iron Rod, 4 Foot long, and about half an Inch Diameter, pointed at each End, but not sharp, being left about the Bigness of a Pin's Head, this being suspended on the Lines; then the Tube being rubb'd, and held near one End of the

Rod, and then the Finger or Check being put near either End of the Rod, the Effect was the same as when an Animal had been suspended on the Lines, with respect to the pricking Pain we felt.

5. At Night we made the luminous Part of the Experiment, suspending the Iron Rod on the silk Lines; then applying one End of the Tube to one End of the Rod, not only that End had a Light upon it, but there proceeded a Light at the same Time from the other, extending in Form of a Cone, whose Vertex was at the End of the Rod, and we could plainly see that it consisted of Threads, or Rays of Light, diverging from the Point of the Rod, and the exterior Rays being incurvated. This Light is attended with a small hissing Noise; every Stroke we give the Tube, causes the Light to appear: the Hissing seems to begin at that End of the Rod next the Tube, and as it comes, increases in its Loudness, but it is so small as not to be heard without good Attention, and by those only that stand at that End of the Rod from whence the said Light proceeds.

Mr. *Godfrey* being desirous to see these Experiments, I repeated them, by laying a Rod of Iron upon a Cake of Shell-Lake, which was laid upon a Glass Vessel; but the Effects being much the same with what has been above-mentioned, I shall not need to mention any other Particulars.

1. I shall now proceed to give some Account of the Experiments I have made since my Return to *London*, which was in *September* last. I caused three Iron Rods to be made, one of four Feet long, two, each three Feet in Length; one of these was made tapering toward the Ends, and pointed as that of four Feet

was

was; the other pointed at one End, and the other End not pointed, the Diameter of the Rods about half an Inch; they were first forged, then filed and burnished. With these I made the following Experiments: When any of them were laid either upon the Brims of hollow Cylinders of Glass well warmed, or upon Cakes of Rosin and Bees Wax, or upon those of Sulphur, the Phenomenon was the same as when they had been suspended on Silk Lines: But now I discover'd another very surprizing one, *viz.* that after the Tube had been applied, and the Light seen at both Ends, upon my going to the other End of the Rod, when there was no Light to be seen, upon holding my Hand at some distance from it, then moving my Hand towards it with a pretty swift Motion, there issued from that Point of the Rod a Cone of Light, as when the Tube had been applied to the other End; and upon repeating this Motion of my Hand, the same Phenomenon appear'd for five or six times successively, only the Rays were each time shorter than the other; these Lights are also attended with a hissing Noise: That Light which appears upon that End next the Tube, when it is held obliquely to the Axis of the Rod, has its Rays tending towards it: All the Time I am rubbing the Tube, these Flashes of Light appear upon every Motion of my Hand up or down the Tube, but the largest Flashes are produced by the Motion of my Hand downwards.

2. When two or three Rods are laid either in a right Line, or making any Angle with each other, or either touch, or are at a small Distance from one another, the Tube being applied to one of their Ends, the furthest End of the further Rod, exhibits the same Phenomena as one single.

AN

3. An Experiment with the Rod that was pointed at but one of its Ends. When the Tube is applied to the other End of the Rod, the Point gives the same Appearance and alike Effect with the Rods, that are pointed at each End; but the great End of the Rod, when the Hand or Check is applied near it, gives but one single Snap; but this is much louder than the greatest of those from the Point of the Rod, and one feels a little more Pain by it.

4. I caused an Iron Ball to be forged, and then turned and burnished; 'twas two Inches Diameter, which being placed on a wooden Stand, that had a small Concave at the Top, in which the Ball was placed; the Stand being set upon a Cylindrick Glass, then the excited Tube being applied near the Ball, there proceeded a Stream of Light from it, with a small hissing Noise; then putting my Finger or Check near the Ball, there was no Snapping, nor any Pain felt, yet there appeared a very bright Light.

5. The Rod of four Feet long, being placed upon a Stand, that had a cross Arm with a Groove in it to receive the Rod; then the Stand being placed on the Glass Cylinder, they were set at such a Distance, as that one of the Points of the Rod might just touch the Ball over against its Centre; then going to the other End of the Rod with the prepared Tube, and applying it as usual, when I came to the Ball, the Hand or Check being near it, caused a loud Snap, compared to those made by the Points of the Rods, and the Pain of pricking or burning was more strongly felt, the Light also was brighter and more contracted: I then placed the Rod with its Point at an
Inch

Inch distance from the Ball, and applying the Rod as before, I came to the Ball, and touching it with my Hand or Finger, there not only appeared a Light on the Ball, but there also proceeded a Brush of Light from the Point of the Rod after the same manner as when the Experiments had been made with the Rods only.

6. An Experiment made with the four Feet Rod, and a Brass Plate four Feet square. This was placed upon a Stand, so that the Plate stood perpendicular, the Stand being set on the Cylindrick Glass; then the Rod with its Stand and Glass was set so as that one Point of it was about an Inch from the Centre of the Plate; then the Tube being applied to the other End of the Rod, and after going to the Plate, on striking it gently with my Finger on the back Side, a Light appeared upon the Plate, and at the same time the Brush of Light came out from the Point of the Rod; and when my Hand or Cheek was held near any of the Angles of the Plate, there was a Light came from thence with a small hissing Noise, and the Pricking was felt as when the Experiments were made with the pointed Rods.

7. A Pewter Plate being laid upon the Stand, which had been set upon a Glass Cylinder, the Tube first, and then the Finger applied, there appeared a Light upon the Plate, and the End of the Finger was pushed; and when the Cheek was held near the Edge of the Plate, there was a Snapping heard, but not so loud as when the Iron Rods were used. I then filled the Plate with Water, and applying the Tube and Finger as before, there was the same Light, pushing of the Finger, and Snapping, as when the Experiment was made with the empty Plate. When the Experiment is made with Water by Day-light, by applying the

the End of the Finger near the Surface of the Water, it appears to rise in a little Hill, and upon the snapping Noise falls down again, putting the Water into a waving Motion near the Place where the Water had risen.

—8. I then took a wooden Dish, and placed it upon the Stand first empty; then applying the Tube, and the Finger held near the Dish, there appeared a Light, but no pushing of the Finger nor Snapping: I then filled the Dish with Water, and the Tube being held over the Surface of the Water, there appeared a greater Light than when the Finger had been applied to the empty Dish, but no Snapping, till by holding the Tube after it had been well rubbed, within two or three Inches of the Finger that was held near the Surface of the Water, and then the Finger was pushed, and a snapping Noise heard, as when the Experiment was made with the Pewter Plate.

By these Experiments we see, that an actual Flame of Fire, together with an Explosion, and an Ebullition of cold Water, may be produced by Communicative Electricity; and altho' these Effects are at present but in *minimis*, it is probable, in Time there may be found out a Way to collect a greater Quantity of it; and consequently to increase the Force of this Electric Fire, which, by several of these Experiments (*Silicet magnis componere parva*) seems to be of the same Nature with that of Thunder and Lightning.

S I R,

Your's and the Society's Most Obedient
Humble Servant,

STEPHEN GRAY.

VIII. *An Account of some Electrical Experiments intended to be communicated to the Royal Society by Mr. Stephen Gray, F. R. S. taken from his Mouth by Cromwell Mortimer, M. D. R. S. Secr. on Feb. 14, 1735-6. being the Day before he died.*

EXPERIMENT I.

TAKE a small Iron Globe of an Inch or Inch and half Diameter, which set on the Middle of a Cake of Rosin of about seven or eight Inches Diameter, having first excited the Cake by gently rubbing it, clapping it three or four times with the Hands, or warming it a little before the Fire; then fasten a light Body, as a small Piece of Cork, or Pith of Elder, to an exceeding fine Thread, five or six Inches long, which hold between your Finger and Thumb, exactly over the Globe, at such an Height, that the Cork, or other light Body, may hang down about the Middle of the Globe: This light Body will of itself begin to move round the Iron Globe, and that constantly from West to East, being the same Direction which the Planets have in their Orbits round the Sun. If the Cake of Rosin be circular, and the Iron Globe placed exactly in the Centre of it, then the light Body will describe an Orbit round the Iron Globe, which will be a Circle; but if the Iron Globe be placed at any Distance from the Centre of the circular Cake, then the light Body will describe an [Elliptical] Orbit, which will

will have the same Excentricity as the Distance of the Globe from the Centre of the Cake.

If the Cake of Rosin be of an Elliptic Form, and the Iron Globe be placed in the Centre of it, the light Body will describe an Elliptical Orbit of the same Excentricity as the Form of the Cake.

If the Iron Globe be placed in or near one of the *Focus's* of the Elliptic Cake, the light Body will move much swifter in the *Apogee* Part of the Orbit, than in the *Perigee* Part, contrary to what is observed of the Planets.

EXPERIMENT II.

Take the same or such another Iron Globe, and having fasten'd it on an Iron Pedestal about one Inch high, set it on a Table, then set round it a Glas Hoop or Portion of an hollow Glas Cylinder of seven or eight Inches Diameter, and two or three Inches high: This Hoop must be first excited by warming and gently rubbing it, then hold the light Body suspended as in the first Experiment, and it will of itself move round the Iron Globe from West to East in a circular Orbit, if the Hoop be circular and the Globe stand over the Centre of it, but in an Elliptic Orbit with the same Excentricity, if the Globe does not stand in the Centre of the Hoop, as in the first Experiment, when the Globe does not stand on the Centre of the Cake.

[What will happen if the Hoop be Elliptic, he did not mention; I suppose, he had not an oval Glas Hoop by him.]

EXPERIMENT III.

This same Iron Globe being set on the bare Table, without either the Cake of Rosin or Glas Hoop, the

F f f

small

small light Body being suspended as in Experiments I, II. will make Revolutions round it, but slower and nearer to it than when it is placed on a Cake of Rosin, or within a Glafs-hoop.

R E M A R K S.

He had not yet found that these Experiments would succeed, if the Thread, by which the light Body was suspended, was supported by any other Thing than an Human Hand; but he imagin'd it might happen the same, if the Thread should be supported or fasten'd to any animal Substance whatever; and he intended to have tried the Foot of a Chicken, a Piece of raw Flesh, or the like.

He imagin'd to explain the foregoing Particular, by the following odd Phænomenon, of which, he assur'd me, he was very certain, having often observ'd it, *viz.* If a Man resting his Elbows on his Knees, places his Hands at some small Distance from each other, they will gradually accede to each other, without any Will or Intention of the Man to bring them together; and they will again recede of themselves. In the like manner, the Hand will be attracted by the Body; or the Face of a Man, if he stand near a Wall, will be attracted to the Wall, and be again repelled by it.

He told me, he had thought of these Experiments only a very short Time before his falling sick, that he had not yet tried them with variety of Bodies, but that from what he had already seen of them, which struck him with new Surprize every Time he repeated them, he hoped, if God would spare his Life but a little longer, he should, from what these Phænomena point out, bring his Electrical Experiments to the greatest

8

greatest Perfection; and he did not doubt but in a short Time to be able to astonish the World with a new Sort of *Planetarium* never before thought of, and that from these Experiments might be established a certain Theory for accounting for the Motions of the Grand *Planetarium* of the Universe.

In trying these Experiments since his Death, I have found that the small light Body will make Revolutions round a Body of various Shapes and Substances, as well as round the Iron Globe, if set on the Cake of Rosin; thus I tried with a Globe of black Marble, a Silver Sand-dish, a small Chip-box, and a large Cork. I observed that the Cake, if nothing stood upon it, would in any Part strongly attract the light Body, as held suspended by the Thread; but when the Globe, or other Body, was set upon it, the Edges of the Cake attracted the strongest, and so gradually the Attraction seem'd as it approached the Centre to grow less, till at a certain Distance it was changed into a Repulsion, which proceeded from the Globe, or other Body placed upon the Cake; which very strongly repels the light Body, unless it be held very near it, and then it attracts it strongly. While the light Body is suspended, as in the foregoing Experiments, if you approach the Finger of the other Hand near it, it will fly from the Finger, or be repelled by it with great Vigour.

VI. *A Letter from Stephen Gray, F. R. S. to Dr. Mortimer, Secr. R. S. containing some Experiments relating to Electricity.*

TH E following Lines contain an account of what Electrical Experiments I have made since those I last communicated to the Society which was in *February* last.

February the 18th, I tried what Effect would be produced on several Sorts of Wood with respect to the luminous Part of Electricity : the Wood was made into Rods of the same Form with those Iron Ones mentioned in my former Letter upon this Subject ; the Woods made use of were Fir, Ash and Holly ; these being successively disposed upon Electric Bodies, after the same manner as the Iron Rods had been, the Tube being applied to one End, there appeared a Light on it, but not with so great a Force, nor did the Light extend to so great a length ; neither was the Form of it Conical, but rather Cylindrical ; but the Extremity of it seemed to consist of a short Fringe of Light ; when the Light, that was given to the Rod by the application of the Tube, did cease, upon a motion of my Hand towards the Point of the Rod, the Light came out again, as has been mentioned of the Iron Rods ; but when the Hand or Finger was held near the Point of these wooden Rods, there was no pricking or pushing of the Finger felt, as when the Iron Rods were made use of I had some of these Rods made much bigger at one End than the other, and now applying my Finger

to the larger End, there not only appeared a Light, but the Finger was pushed, more especially when the Holly Rod was made use of, and the Cheak was a little prick'd, but the Smart was not near so great, as when the Iron Rods were used; the great End of the Rod was pointed with a much larger Angle than the lesser one, yet there was very little, if any difference, in the form, or bigness of the Light that proceeded from either End.

Having procured me two pair of Lines made of Worsted Yarn, one of them of a Mazareen Blew, the other of a Scarlet Colour; on the 3d of *April*, I suspended the Boy first on the Blew Lines, and found that all the Effects were the same, as when he was suspended on Lines of Blew Silk: I then suspended him upon the Scarlet Lines, but now though the Tube were as well excited, and the Experiment often repeated, yet there was no Effect produced on him, either of attraction of a pendulous Thread, nor of pricking or burning, by applying one's Hand near him; I then laid one of the Iron Rods first upon the Blew Lines, and all the same Effects were exhibited, as when the same Rod had been laid on Silk Lines of that Colour; but upon laying the same Rod upon the Scarlet Lines, no manner of attraction, &c. was perceived.

In the *Philosophical Transactions*, *Numb.* 422. I gave an Account of the Experiments I made upon the communicative Electricity of Water, and that Water is attracted by the Tube, together with several remarkable Circumstances with which this attraction is attended; but I have now found, that when the Stand with those little Ivory Cups there

mentioned, be set upon any Electrick Body, the same Phenomena are produced, not only by holding the Tube near the Water, but when that is removed, and the Tip of the Finger placed over the Water, *viz.* there is a little Hill, or Protuberance of Water of a Conical Form, from the Vertex of which proceeded a Light and a small Snapping.

May the 6th, we made the following Experiment. The Boy being suspended on the Silk Lines, and the Tube being applied near his Feet as usual; upon his holding the End of his Finger near a Gentleman's Hand, that stood on a Cake made of Shell Lack and black Rosin; at the same time another Gentleman stood at the other side of the Boy with the pendulous Thread; then the Boy was bid to hold his Finger near the first Gentleman's Hand, upon which it was prick'd, and the snapping Noise was heard; and at the same time, the Thread which was by its attraction going towards the Boy fell back, the Boy having lost a great part of his attraction, upon a second moving his Finger to the Gentleman's Hand, the attraction ceased: then the Thread being held near that Gentleman, he was found to attract very strongly; but having since repeated this Experiment, I find that though the attraction of the Boy is much diminished, yet he does not quite lose it, till 2, 3, and sometimes 4 applications of his Finger to the hand of him that stands on the Electrick Body, but without touching him. At another time I caused three Persons to stand, one of them upon a Cake of Shell Lack, &c. the other upon one of Sulphur, the third upon a Cake of Bees-Wax and Rosin; the Persons all holding Hands, the Boy applying his
Finger

Finger near the first Man's Hand, they all three became Electrical, as appeared by the attraction of the Thread, when held near to any of them.

P O S T S C R I P T.

A Repetition of some of these Experiments, and an Addition of some others made June the 10th.

June the 10th in the Morning, I repeated the Experiments with the Wooden Rods, the most material Ones of which were made with the Holly Rod: This being laid on the Glass Cylinder, and a Fir Board about a Foot Square and three tenths of an Inch thick being placed erect upon a Stand, that was set on another Glass Cylinder, so that the Center of the Board was placed near the Point of the Rod, but not to touch it by near half an Inch; then the Tube being held near the great End of the Rod, there issued out a Light from the little End of the Rod, which was that next the Board; and, as the Boy told me, it came along with a hissing Noise, and struck against the Board: When he touched the Board, there was a Light; and, at the same time, another on the End of the Rod, but he heard no snapping nor pricking of his Finger, as when the Brass Plate and Iron Rod were made use of.

Experiments with the Scarlet and Blue Worsted Yarn repeated.

When the Boy was suspended upon the Scarlet Lines, he attracted the white Thread at a very small Distance, but the Attraction ceased in about 6 or 7 Seconds of Time. Then the Boy being taken off, an Iron Rod was laid on the Lines, but there was

no attraction of the Thread by the Body of the Rod ; but when the Thread was held near either of the pointed Ends of it, there was a small Repulsion of it, and in the Dark a very small Light was seen at each End of the Rod.

When the Boy was suspended upon the Blue Lines, he attracted the Thread to him when it was held at least a Foot distance from him, and continued his attraction to near 75 Seconds, the Iron Rod continued its attraction not more than 36 Seconds.

Experiments made in the Afternoon upon the Boy when he was suspended upon Silk Lines of several Colours.

When he was suspended on the Blue Lines, he continued his Attraction 50 Minutes, on the Scarlet Lines 25 Minutes, on the Orange coloured Lines 21 Minutes.

By these Experiments we see the Efficacy of Electricity upon Bodies suspended upon Lines of the same Substance, but of different Colours, and also that the Attraction continues much longer upon Silk than upon Yarn, and consequently Silk is the properest Body we can make use of to suspend those Bodies upon, to which we would communicate an Electricity : But of this Subject more when I shall reassume the Experiments concerning the Influence of Colours upon Electricity ; who am,

S I R,

Charter House,
June 12, 1735.

*Your's and the Society's most
Humble and obedient Servant,*

Stephen Gray.

II. Mr. Stephen Gray, F. R. S. his last Letter to Granville Wheler, Esq; F. R. S. concerning the Revolutions which small pendulous Bodies will, by Electricity, make round larger ones from West to East as the Planets do round the Sun.

I HAVE lately made several new Experiments upon the projectile and pendulous Motion of small Bodies by Electricity, by which small Bodies may be made to move about larger ones, either in Circles or Ellipses, and that either concentrical or excentrical to the Center of the larger Bodies about which they move, so as to make many Revolutions about them; and this Motion will be constantly the same Way that the Planets move about the Sun, viz. from the Right to the Left, or from West to East: But these little *Planets*, if I may so call them, move much faster in their *Apogee*, than in the *Perigee* Parts of their Orbits; which is, as you very well know, directly contrary to the Motion of the Planets about the Sun. I have not yet communicated these Experiments to the Royal Society, being in hopes of making some farther Discovery, or at least of shewing them after somewhat more elegant a manner than I make them at present, when you may expect to hear a farther Account of them from

S I R,

Your most Obedient
Humble Servant,
Stephen Gray.

London, Feb. 6th,
1736.

Philosophical transactions of the Royal society of London :

giving some accompt of the present undertakings, studies,

and labours of the ingenious in many considerable parts

of the world

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