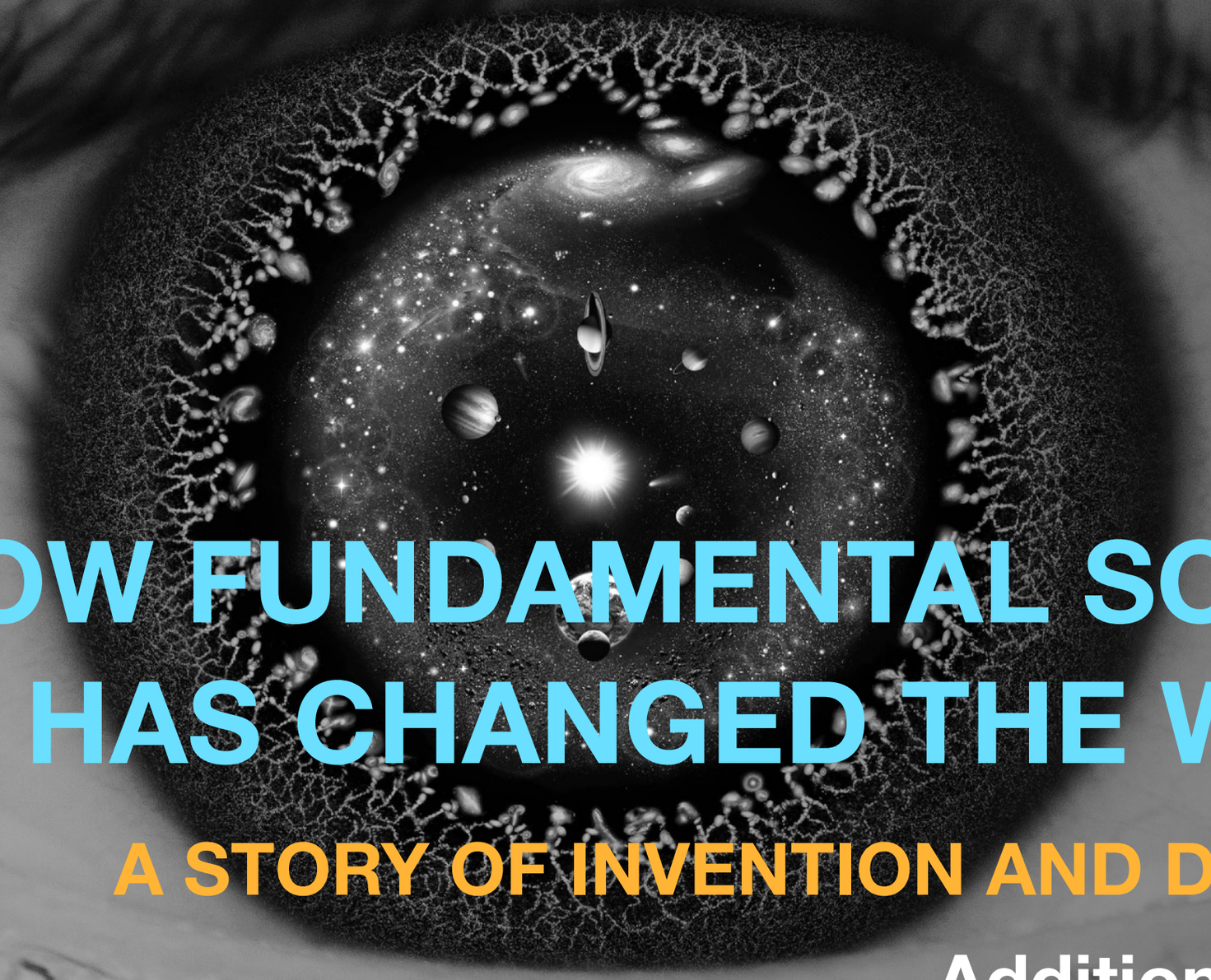
THE UNIVERSITY OF CHICAGO

ENRICO FERMI INSTITUTE



HOW FUNDAMENTAL SCIENCE HAS CHANGED THE WORLD

A STORY OF INVENTION AND DISCOVERY

Additional Material

Philipp Windischhofer

October 21, 2023

Composite image created by combining representation of universe sphere by Pablo Carlos Budassi with human eye by Kamil Saitov (Google Commons).

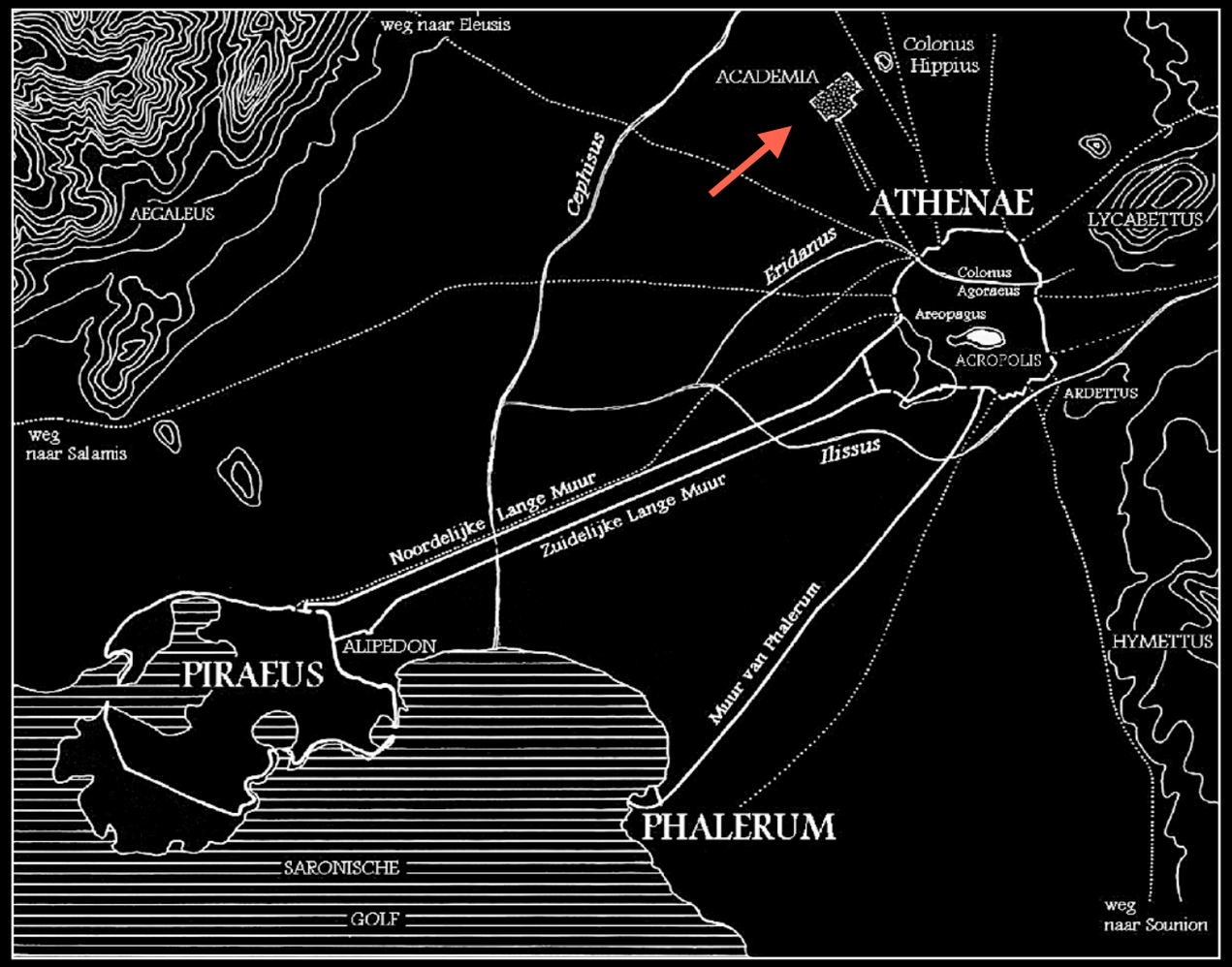
What is the nature of electricity?

Back to ancient Greece (once again)

Plato

Life at the academy

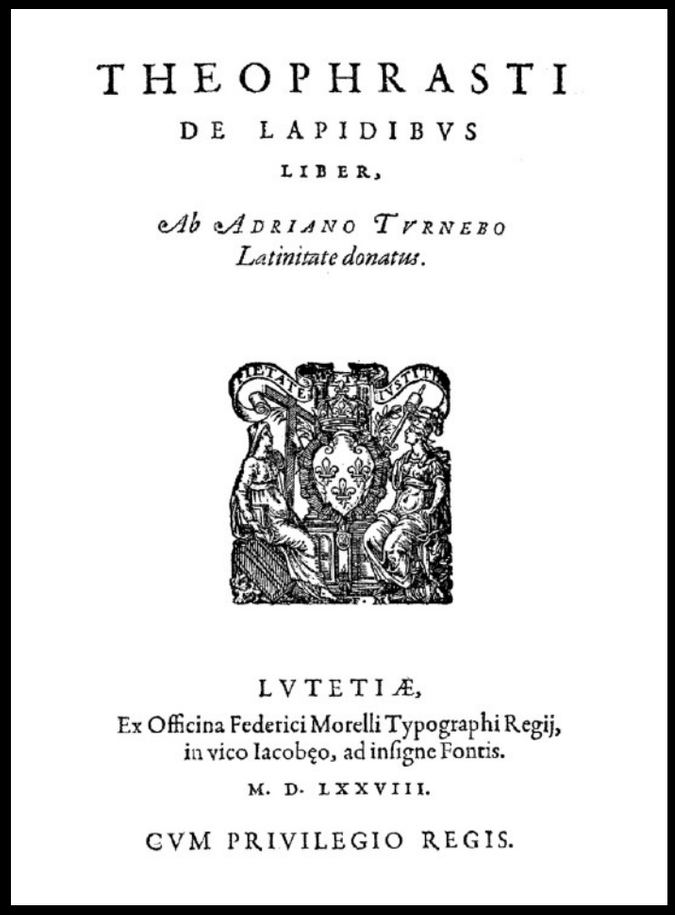
His “academy” near Athens



Theophrastus

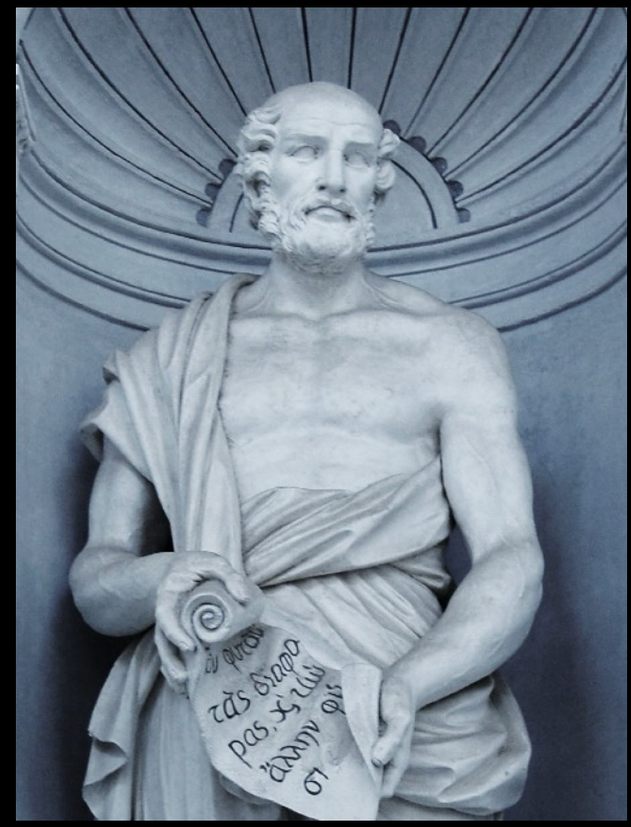
Botanist, physicist, mineralogist, psychologist

“Enquiry into plants”
“Father of botany”


THEOPHRASTI
DE LAPIDIBVS
LIBER,
Ab ADRIANO TVRNEBO
Latinitate donatus.

LVTETIÆ,
Ex Officina Federici Morelli Typographi Regij,
in vico Iacobęo, ad insigne Fontis.
M. D. LXXVIII.
CVM PRIVILEGIO REGIS.

“On Stones”



In the Palermo botanical garden

“Theophrastos” = “godly phrased”
Nickname given to him by Aristotle

Living with natural electricity

Theophrastus (~300 BC): “On Stones”

“[Amber] has the power of attraction, and some say that it not only attracts straws and bits of wood, but also copper and iron, if the pieces are thin […]”

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“Static electricity” *“Triboelectricity”*

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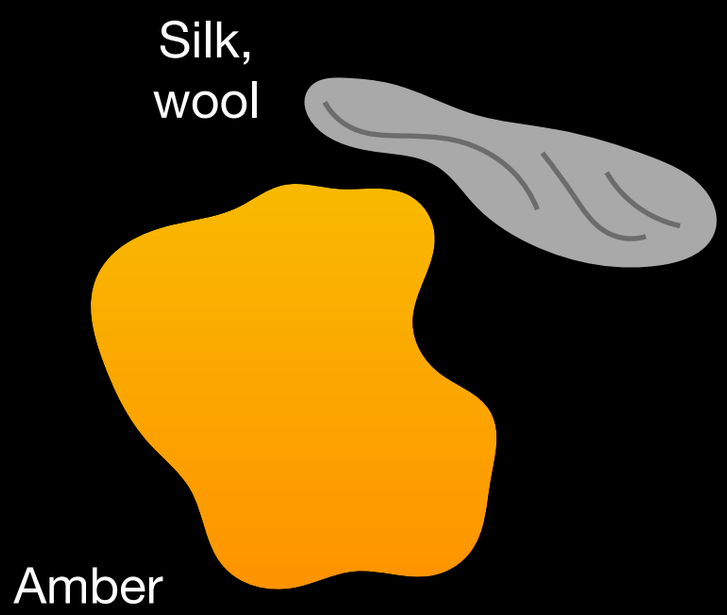

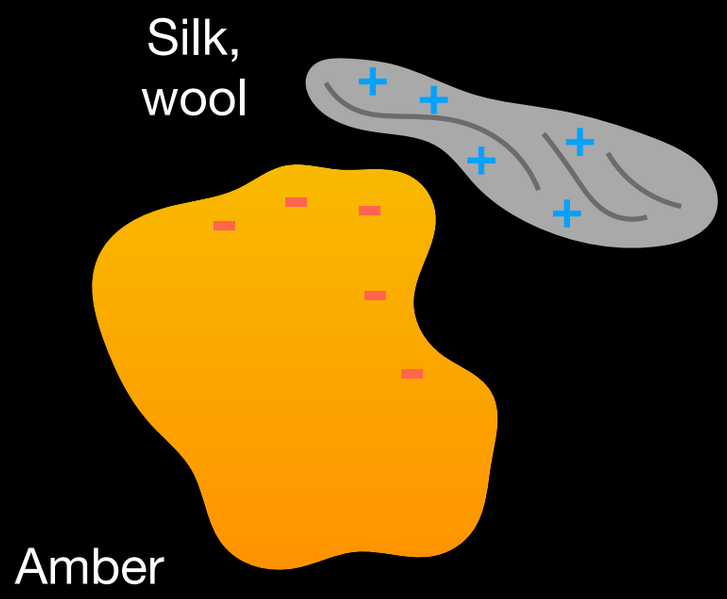

Living with natural electricity and magnetism

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Today: *lodestone*

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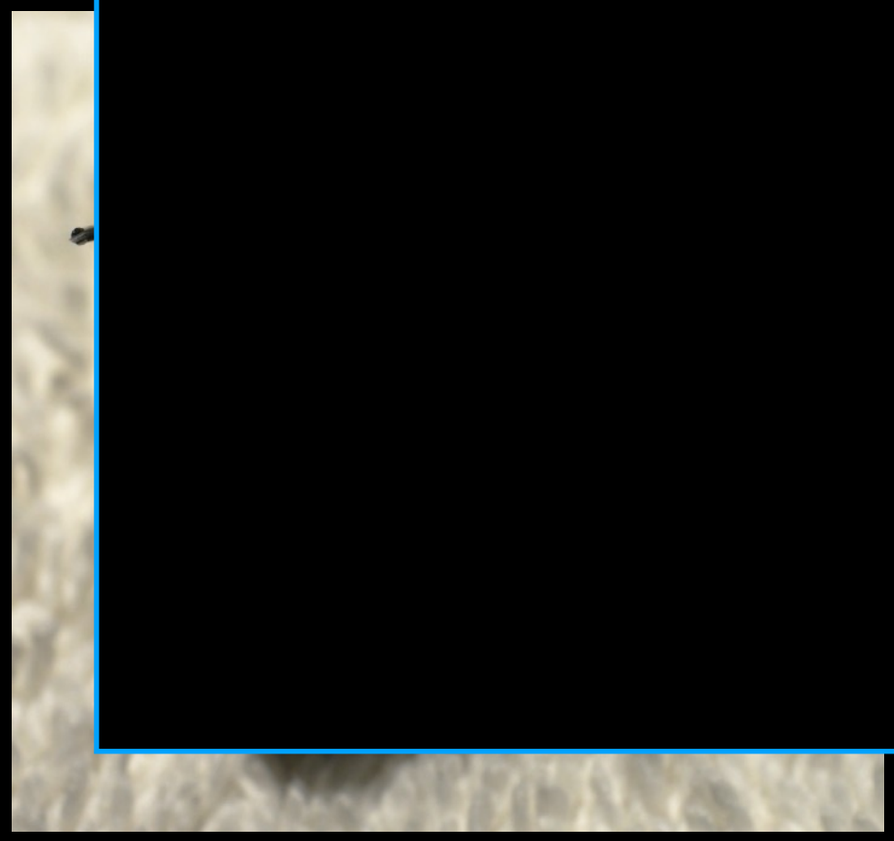
It's the gods!

Plato *(Ion, 380 BC):*



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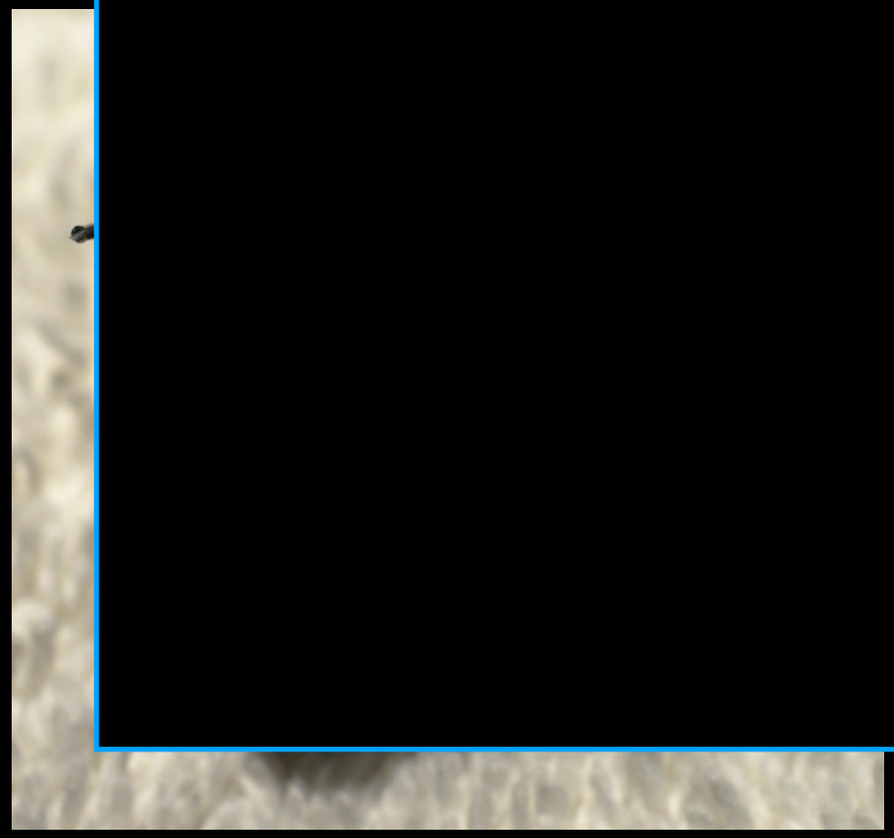
Plato *(Ion, 380 BC):*

"There is a divinity contained in the stone which Euripides calls a magnet […]



Living with natural electricity and magnetism

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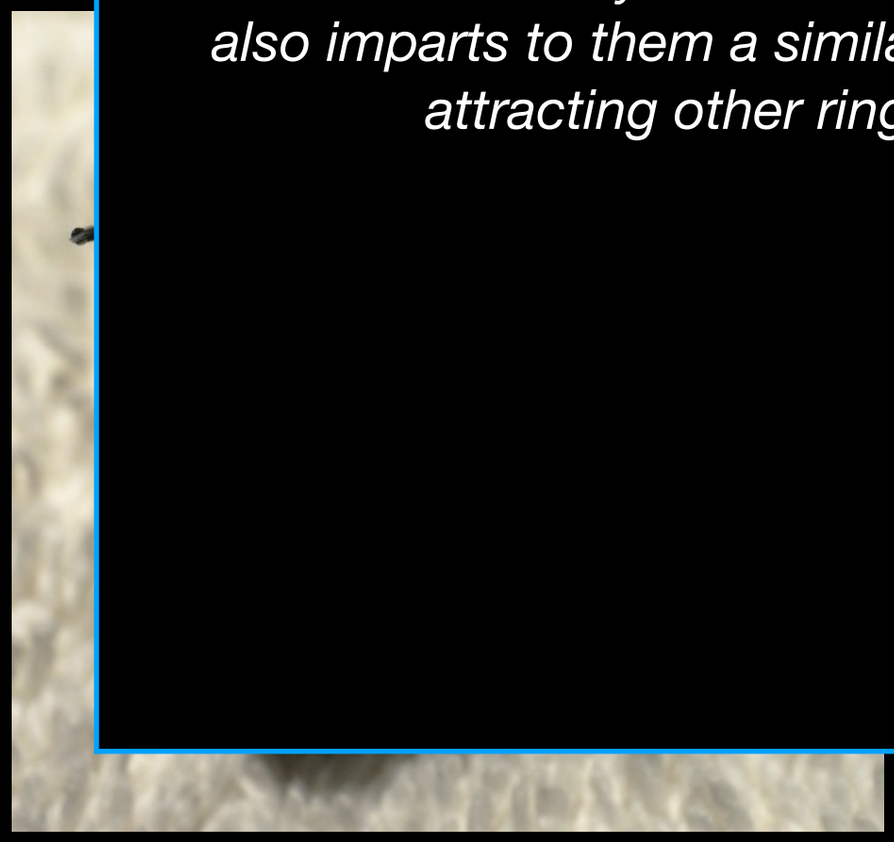
"There is a divinity contained in the stone which Euripides calls a magnet […] This stone not only attracts iron rings, but also imparts to them a similar power of attracting other rings;



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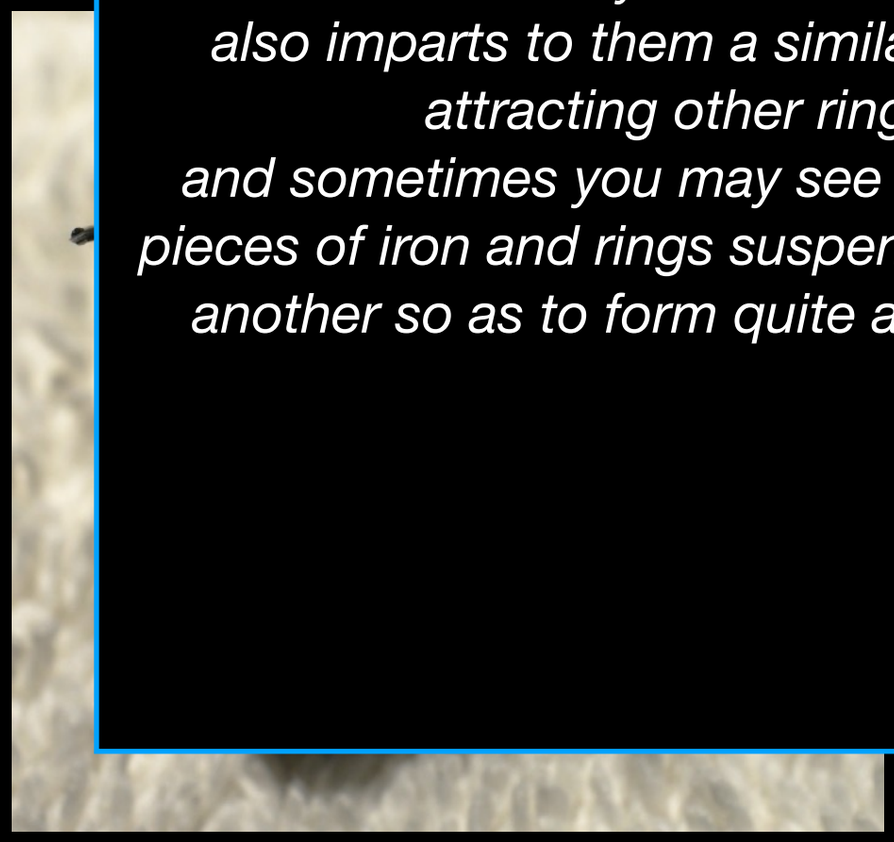
and sometimes you may see a number of pieces of iron and rings suspended from one another so as to form quite a long chain:



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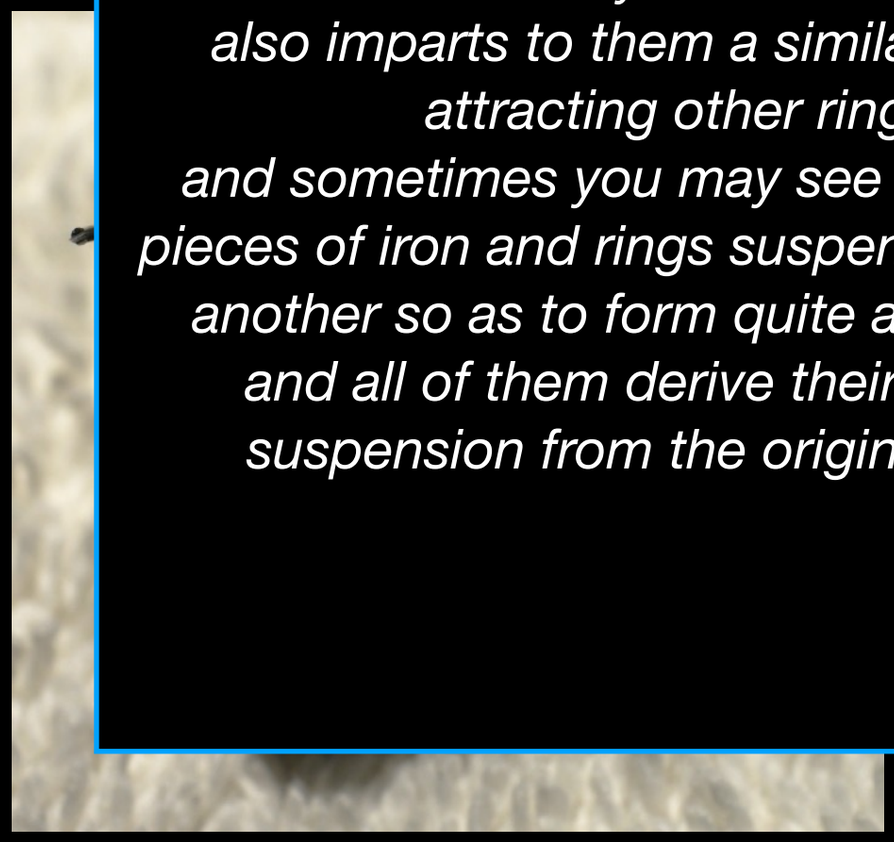
and sometimes you may see a number of pieces of iron and rings suspended from one another so as to form quite a long chain:
and all of them derive their power of suspension from the original stone."



Magnetism takes off

Lodestone compass (Han Dynasty, ~200 BC)

“South-pointing Fish”

First used for divinations, navigation by 11th century

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Pierre de Maricourt (1269)

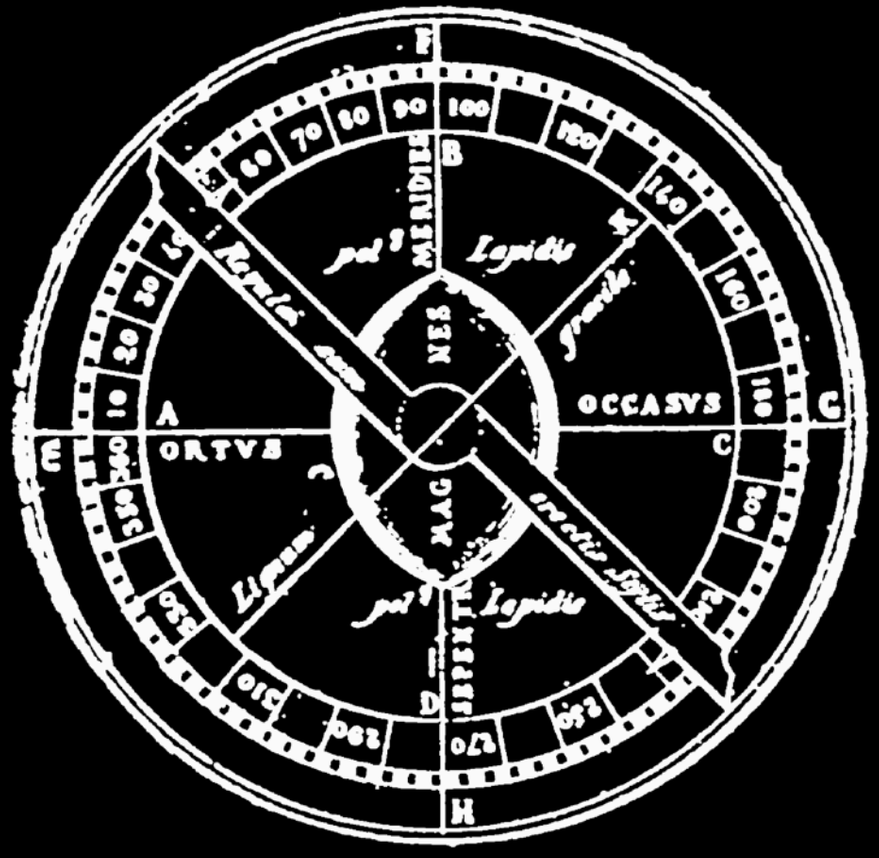

FIG. I.—AZIMUTH COMPASS

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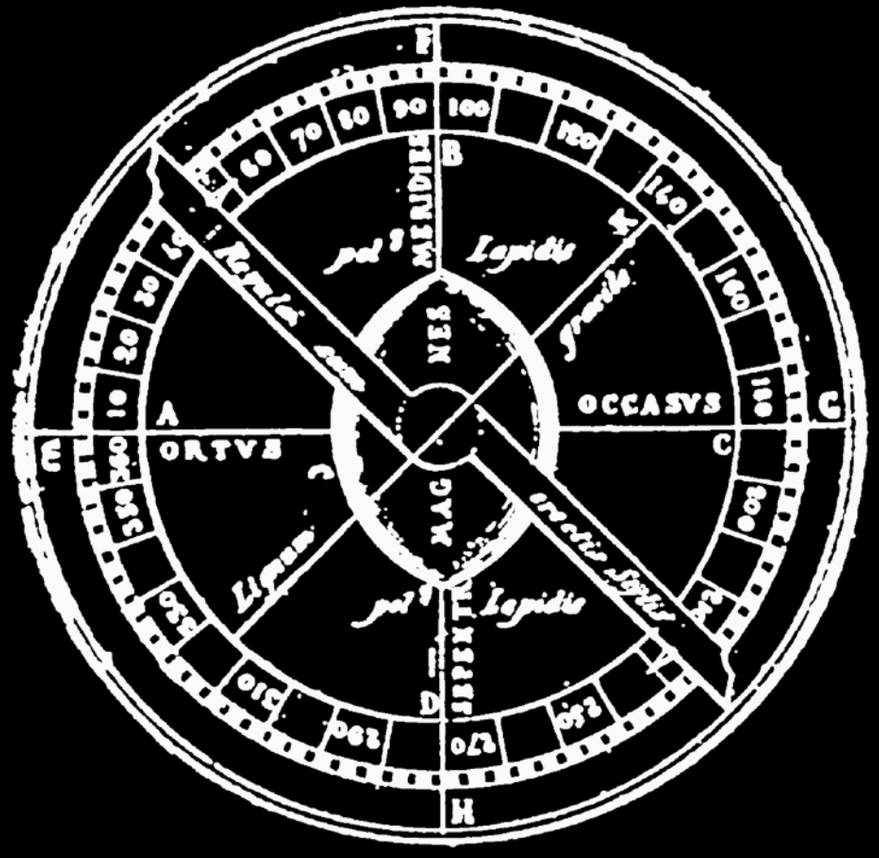

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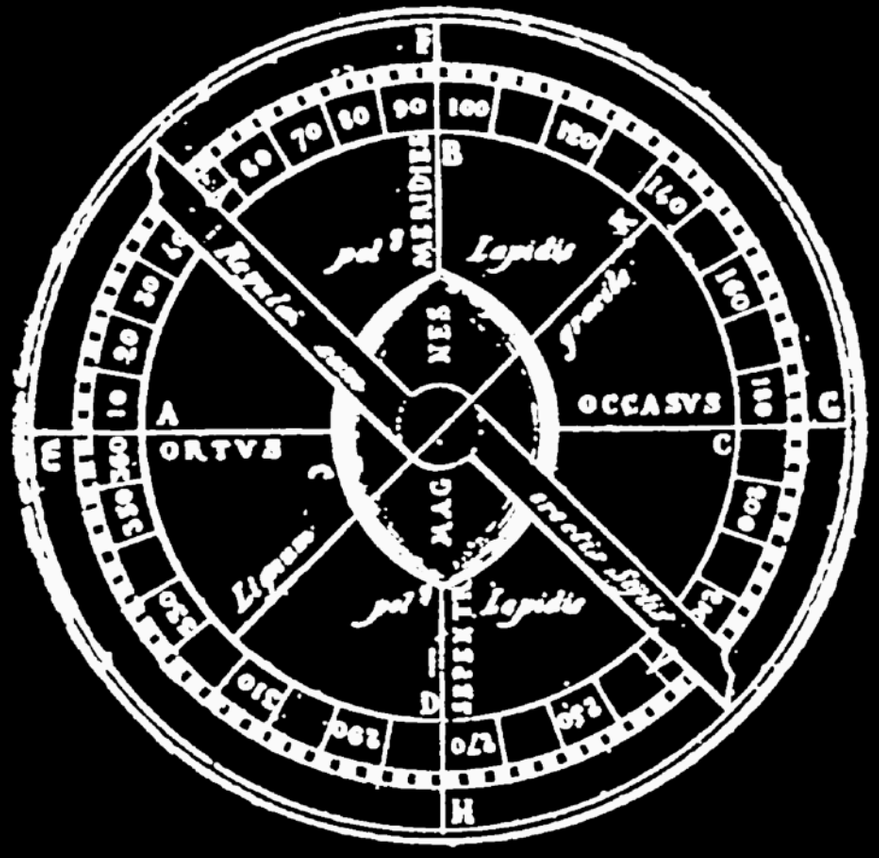

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“Even if the stone be moved a thousand times away from its position, it will return thereto a thousand times, as by natural instinct.“

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Mathematician, physicist, writer, and Lodestone anatomist

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At your earnest request, I will now make known to you, in an unpolished narrative, the undoubted though hidden virtue of the lodestone,

Pierre de Maricourt

Mathematician, physicist, writer, and Lodestone anatomist

From the trenches at Lucera:

“Dearest of friends,

At your earnest request, I will now make known to you, in an unpolished narrative, the undoubted though hidden virtue of the lodestone, concerning which philosophers up to the present give us no information, because it is characteristic of good things to be hidden in darkness until they are brought to light by application of public utility.”

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Undoubtedly, all these lines will meet in two points; one of these is the north pole, the other the south pole.”

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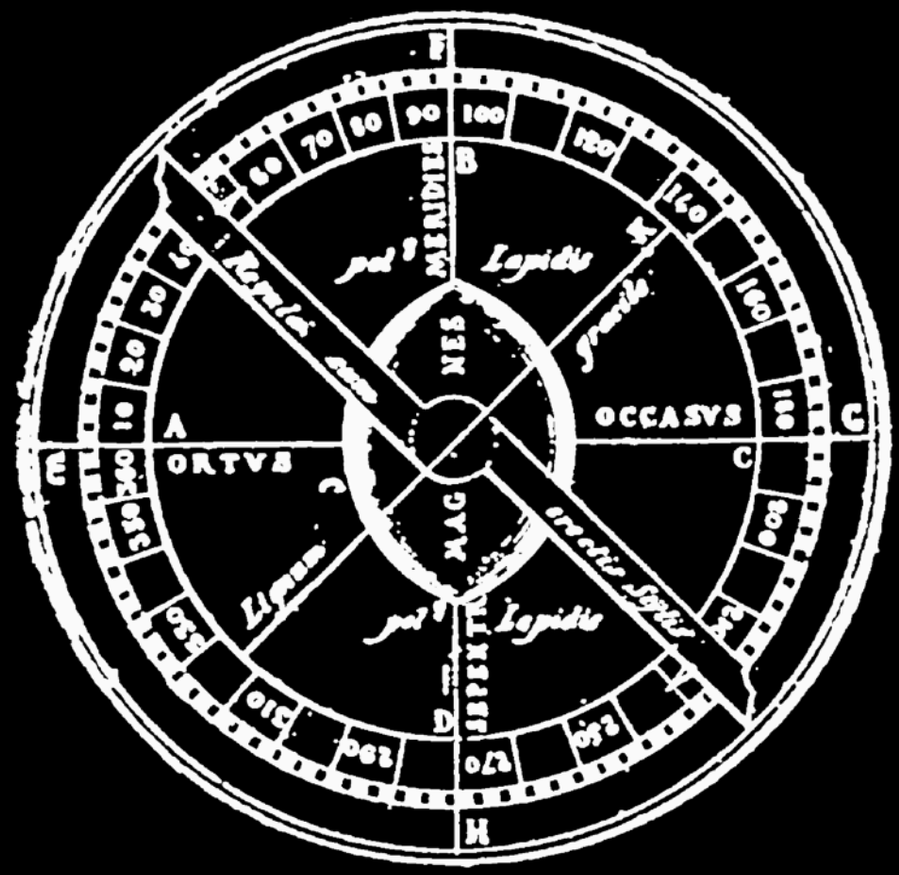

FIG. I.—AZIMUTH COMPASS

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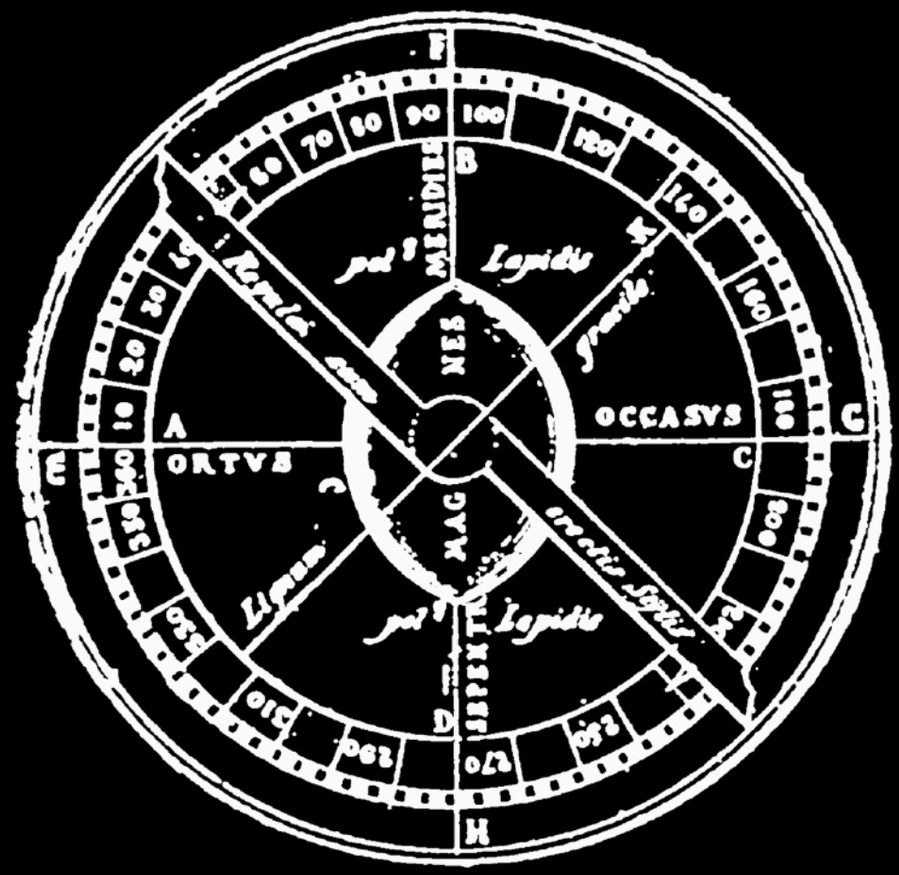

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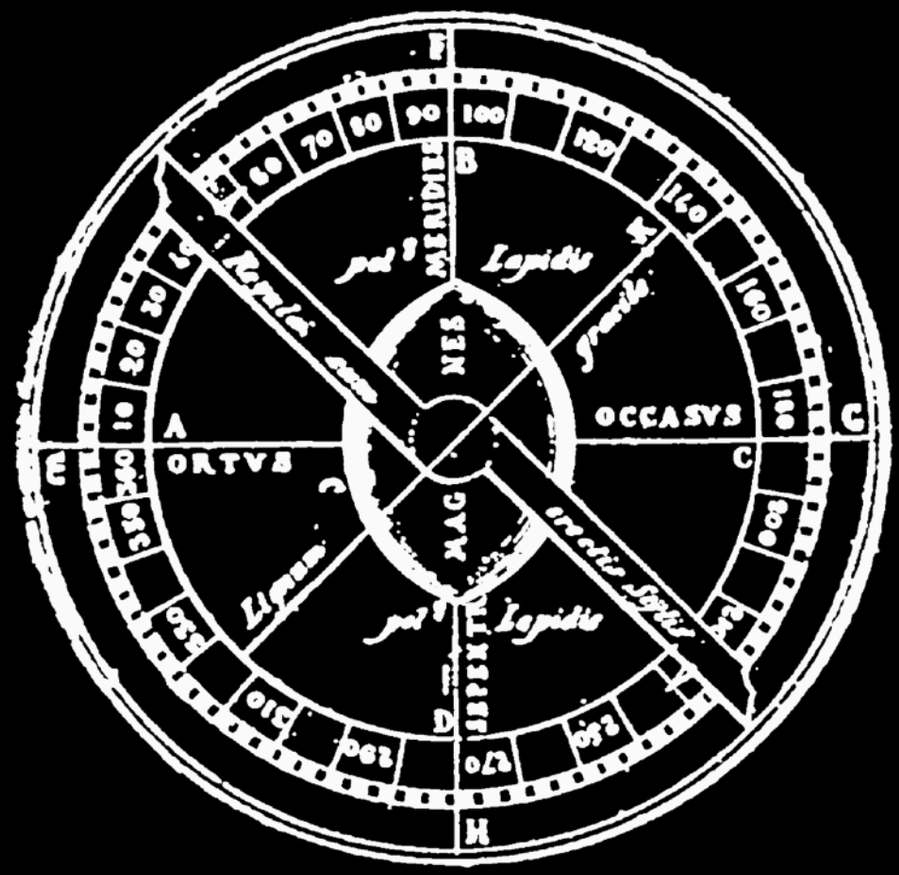

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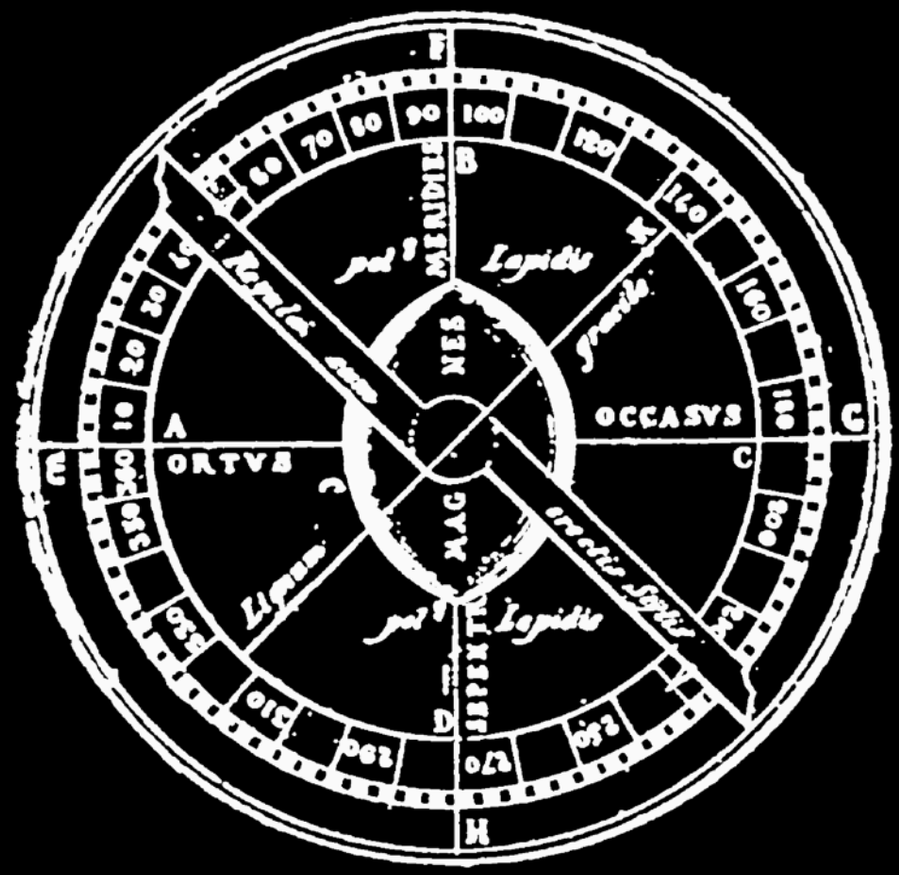

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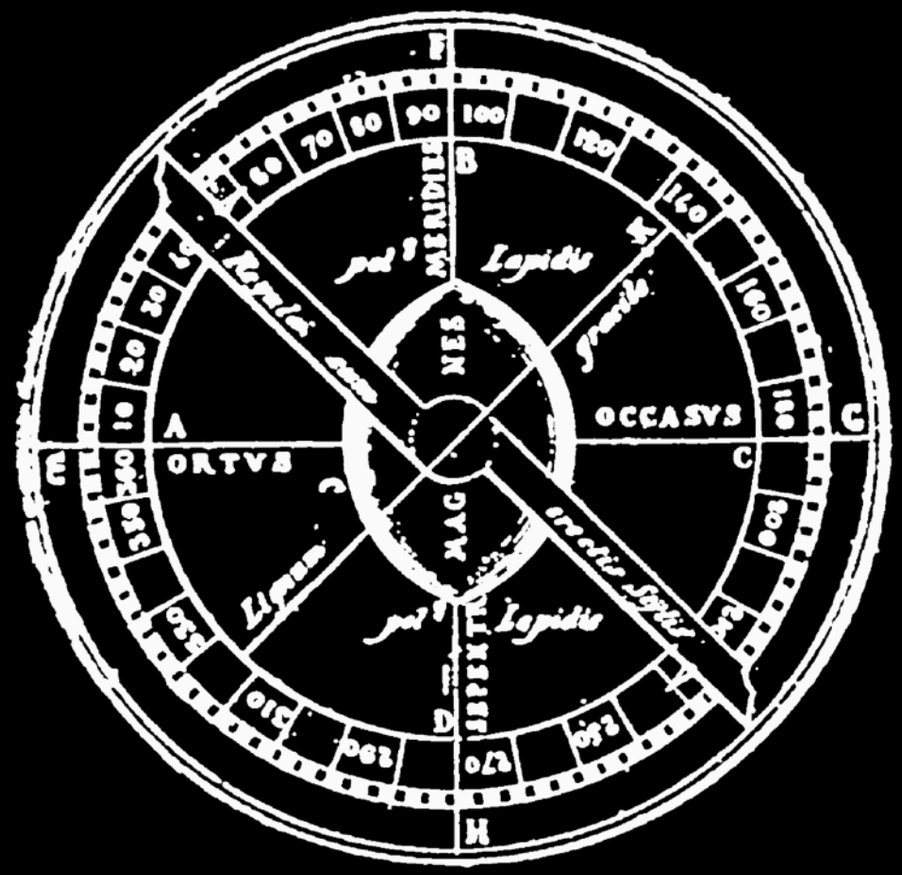

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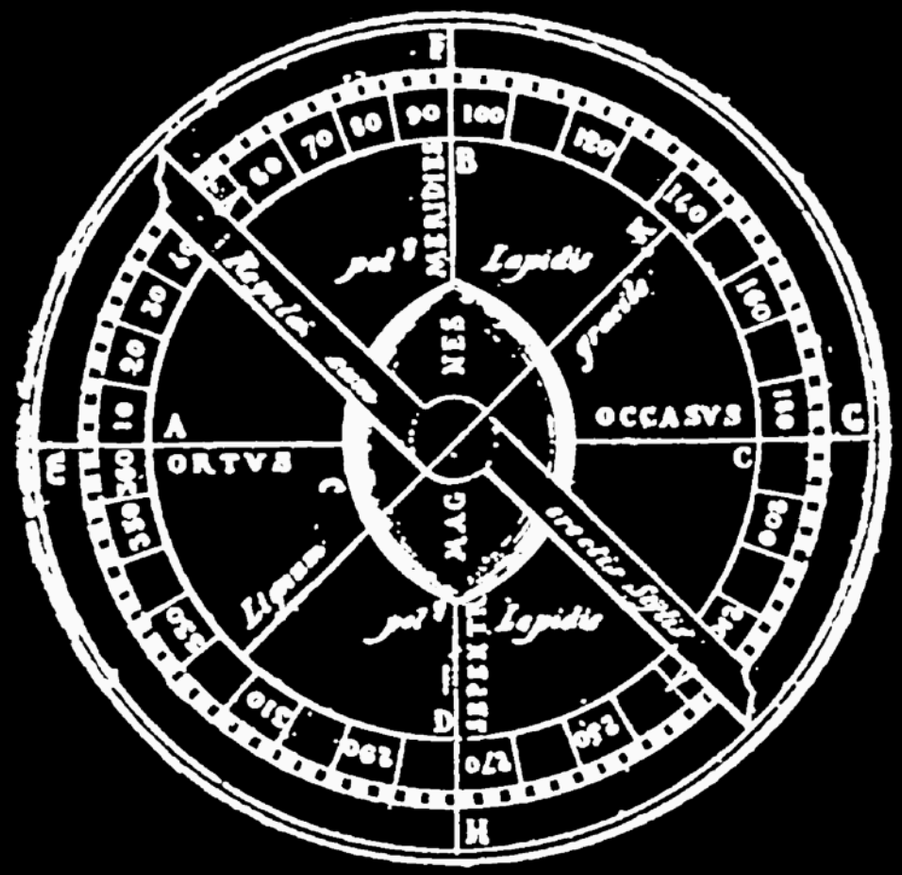

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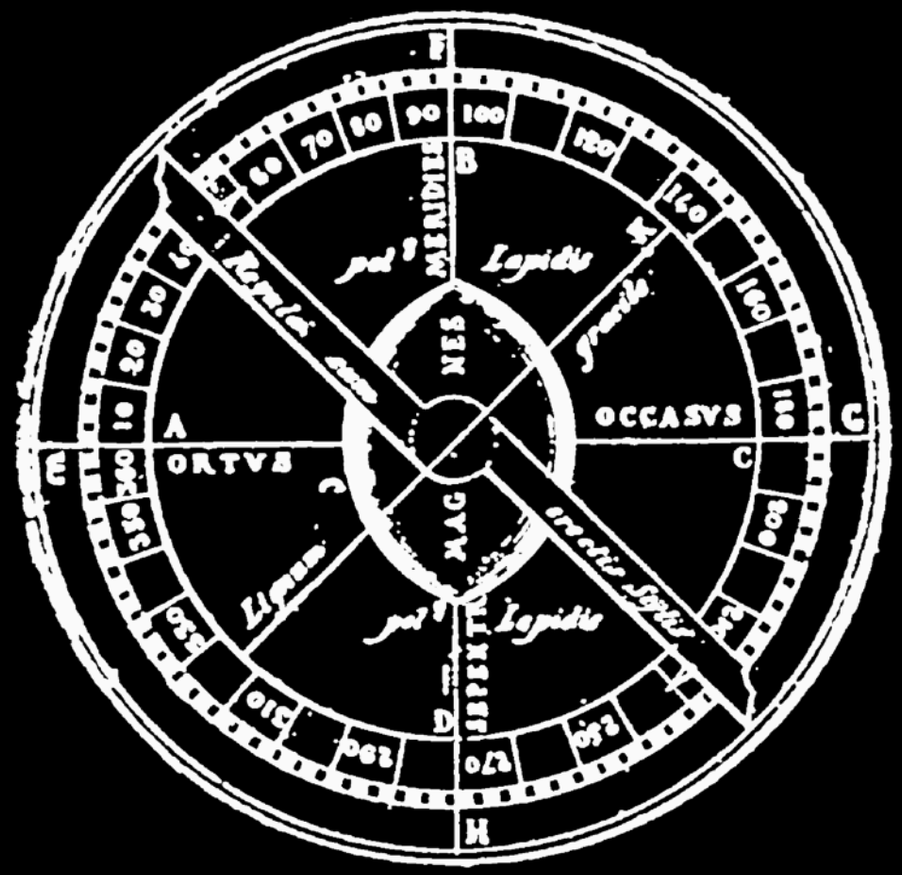
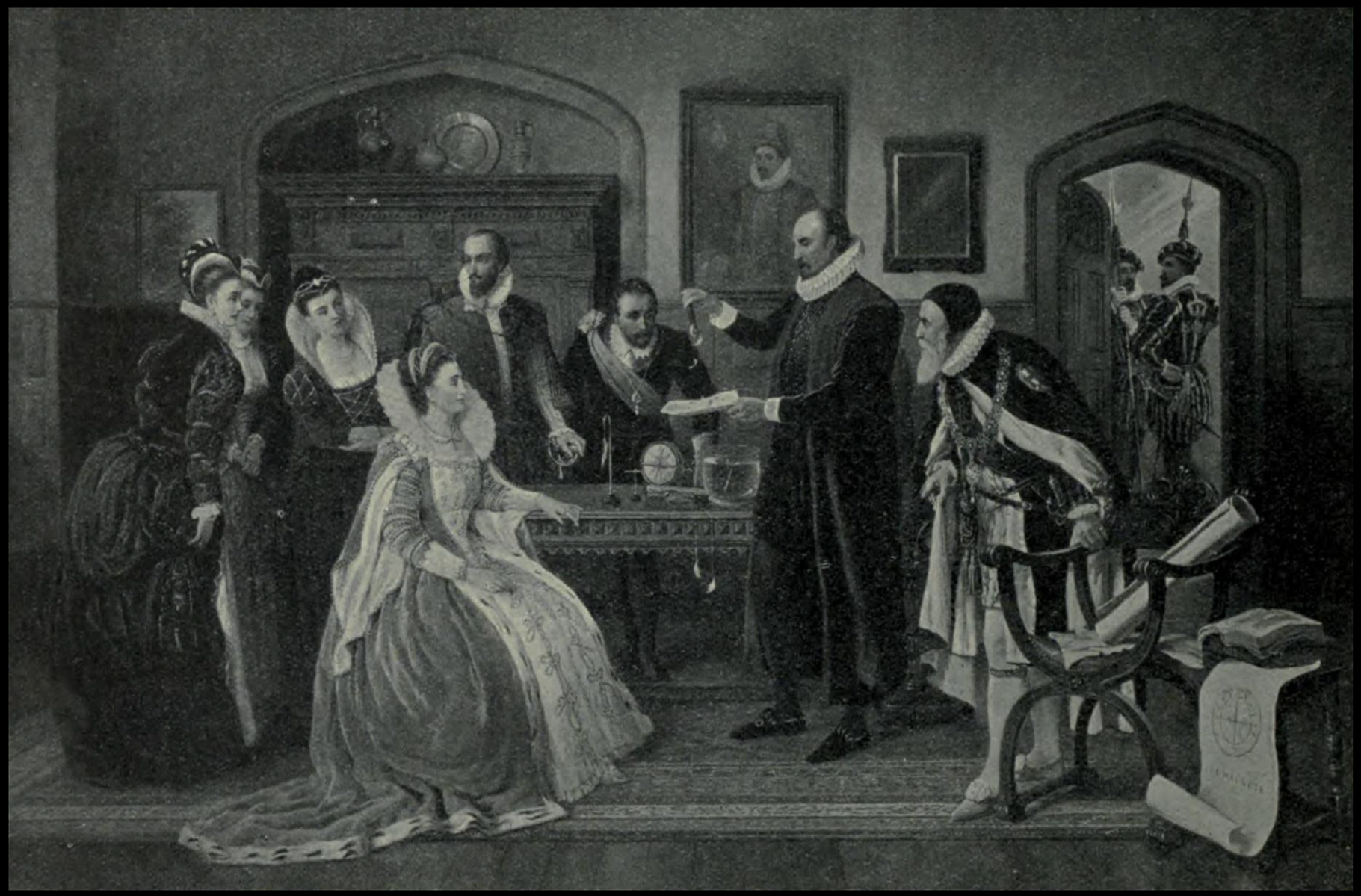


FIG. I.—AZIMUTH COMPASS

William Gilbert

English physician, physicist, natural philosopher



Physician to Queen Elizabeth I,
here demonstrating experiments in front of her

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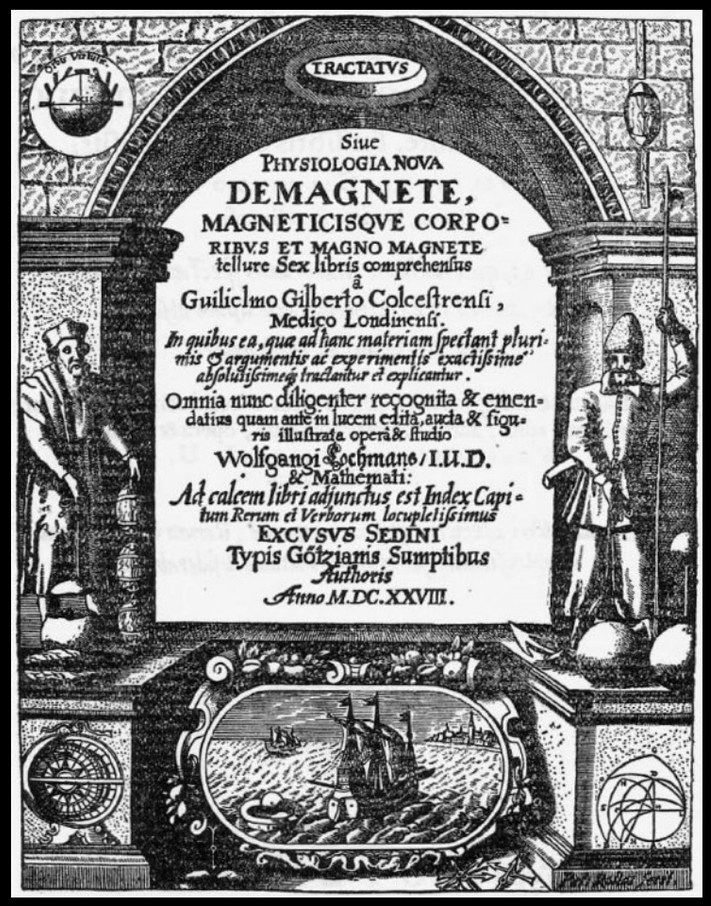
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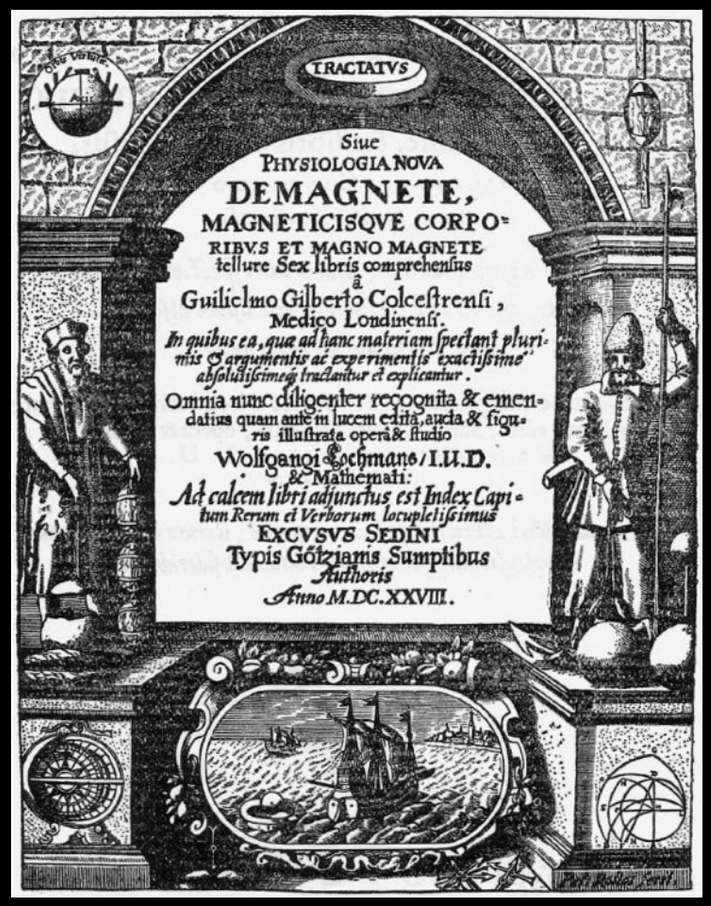
"On the Magnet and Magnetic Bodies, and on That Great Magnet the Earth"
(published 1600)

William Gilbert

English physician, physicist, natural philosopher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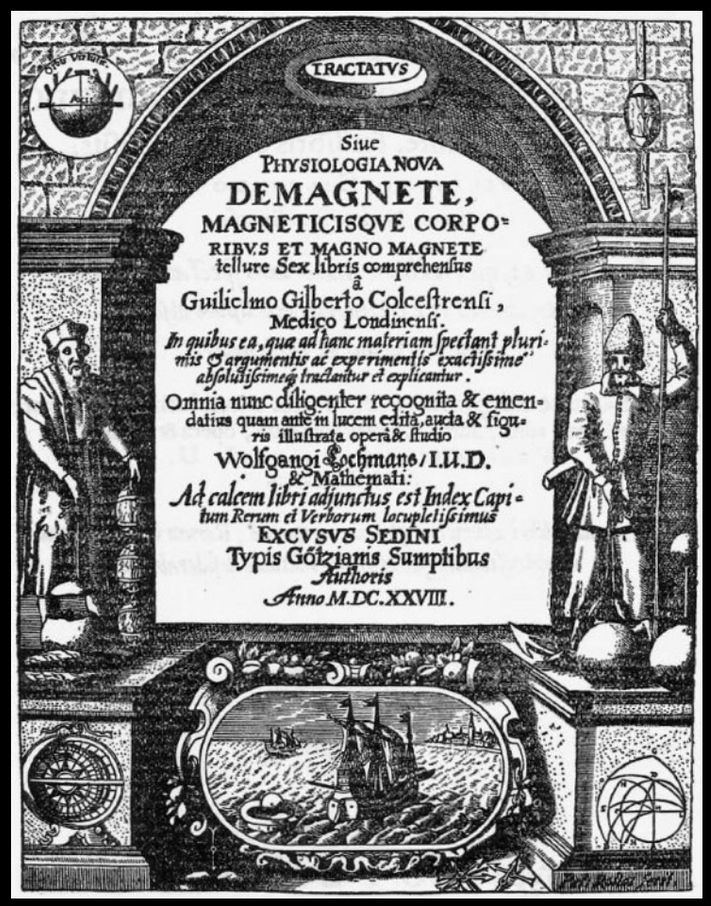
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"And now, what is it that produces the movement?"

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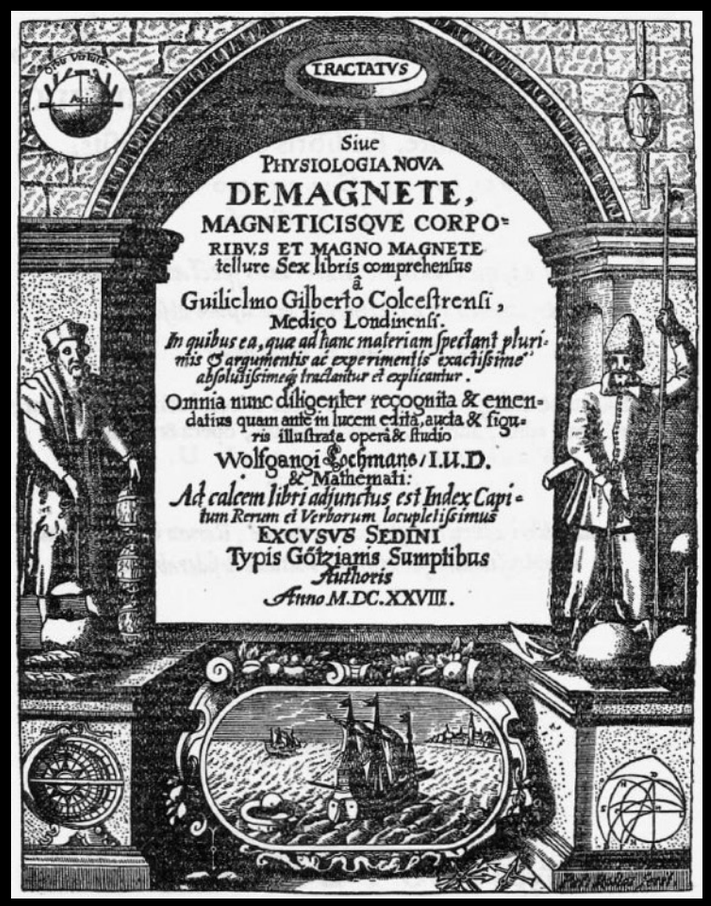
English physician, physicist, natural philosopher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"Is something imperceptible for us flowing out of the substance into the ambient air?"

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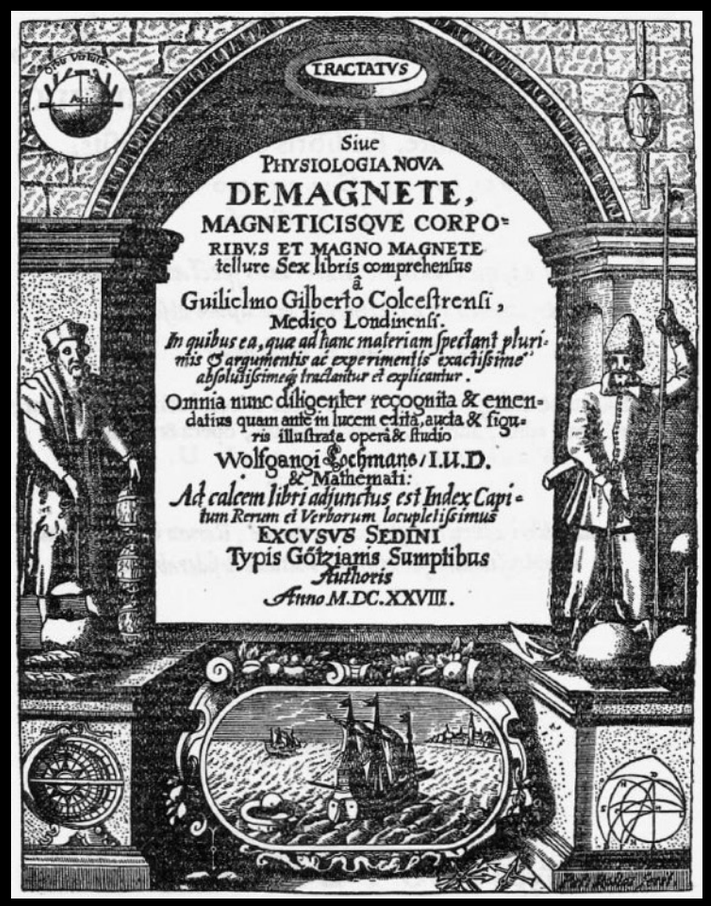
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tellure Sex libris comprehensus

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Medico Londinensi.

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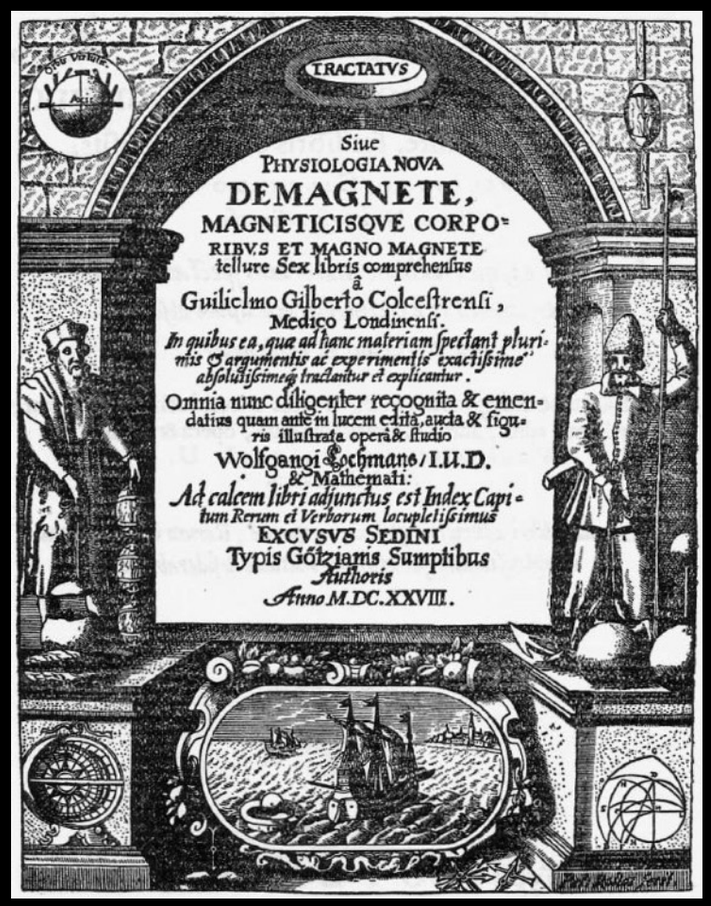
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"An amber that will attract bodies from a considerable radius will cause no motion to a candle flame."

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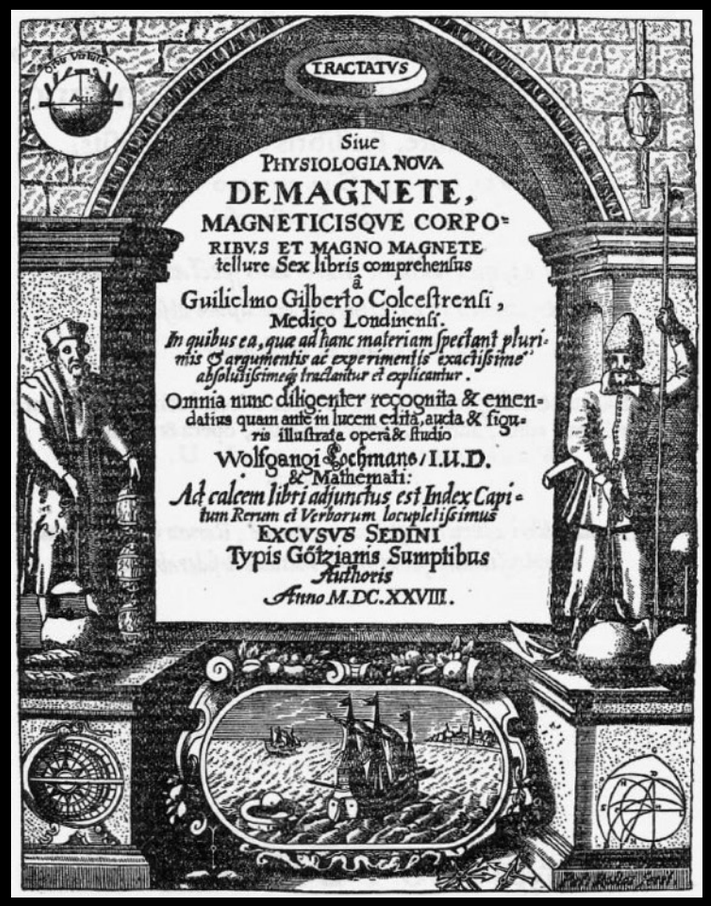
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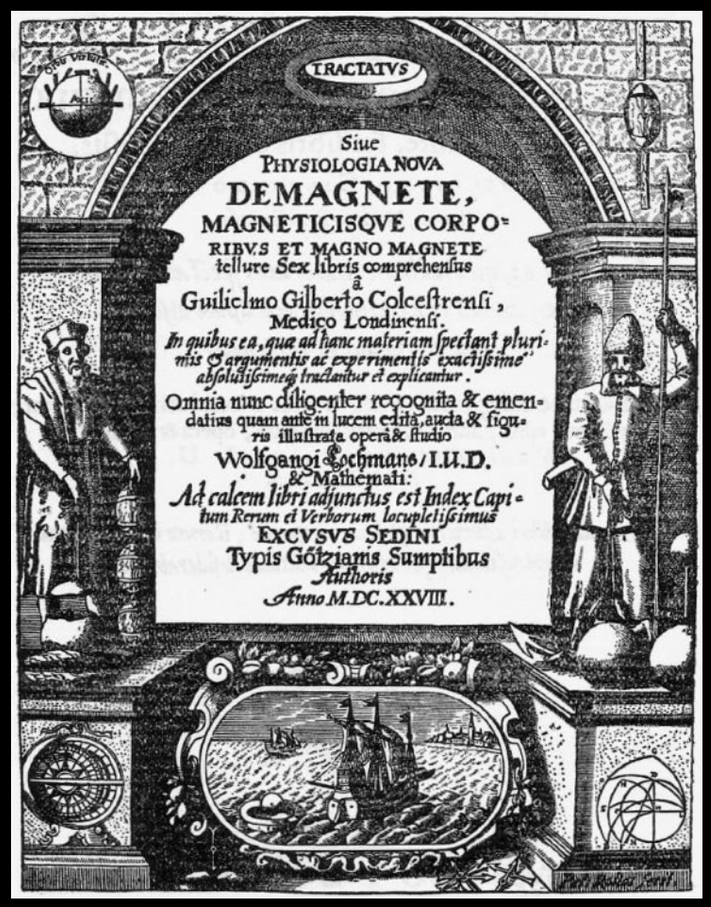
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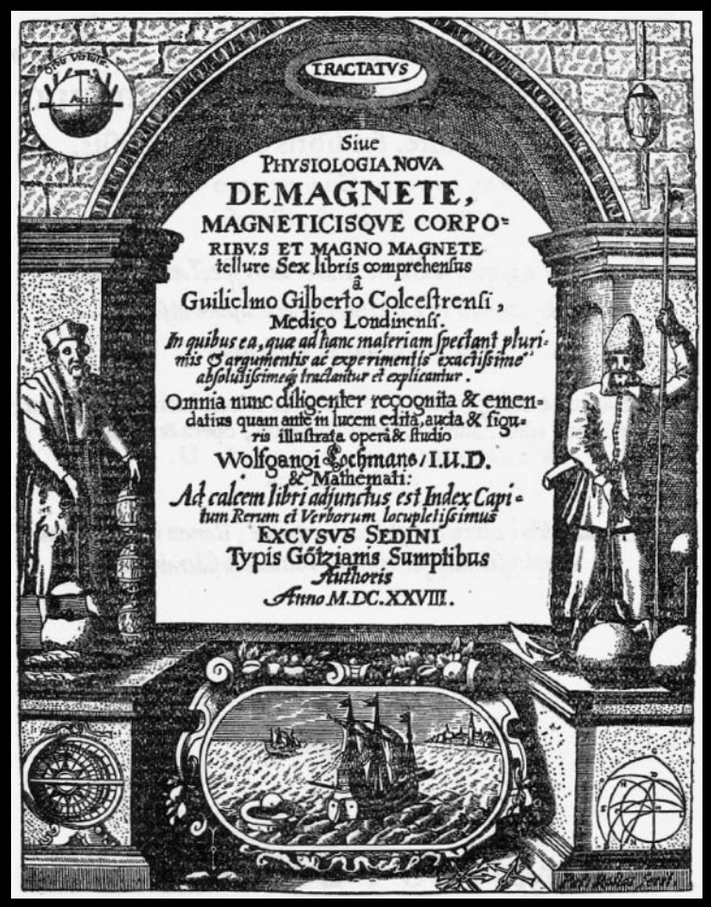
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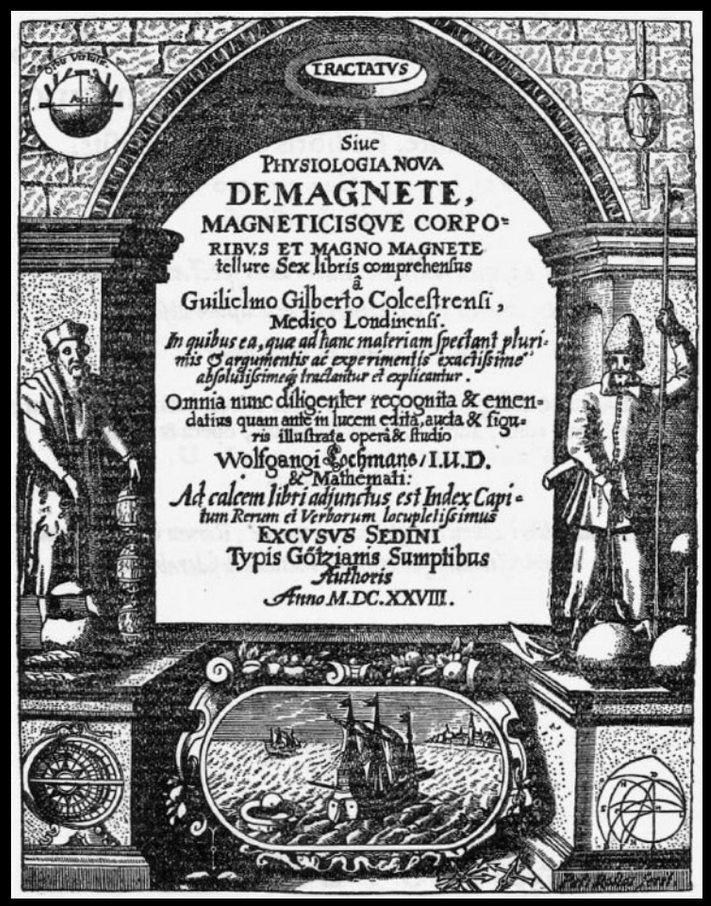
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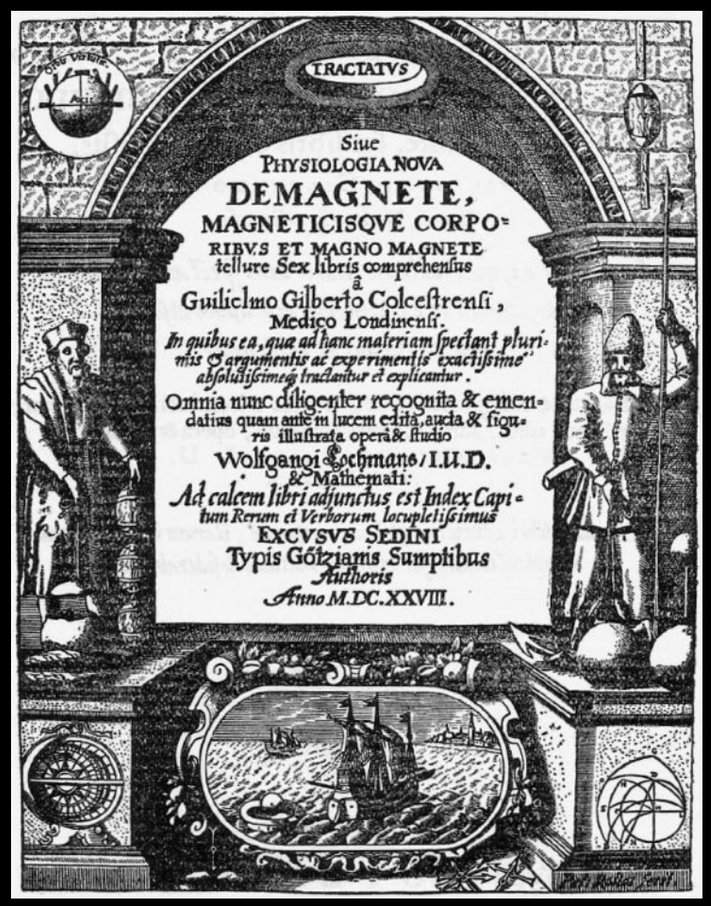
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"[…] the same is done by glass, diamond, sapphire, carbuncle, iris stone, opal, amethyst, English gem, beryl, rock crystal […]"

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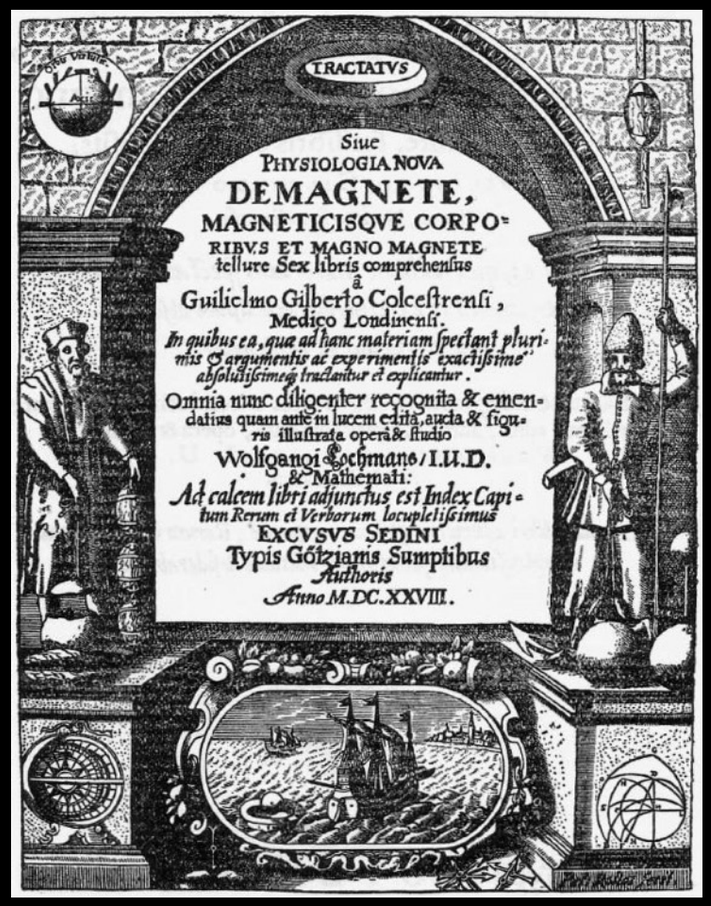
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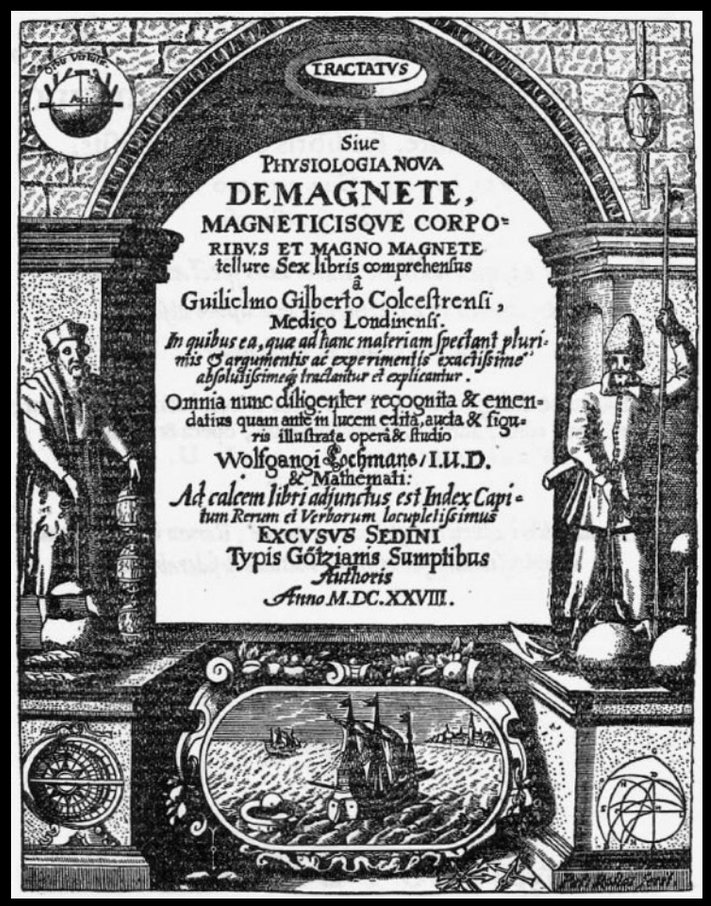
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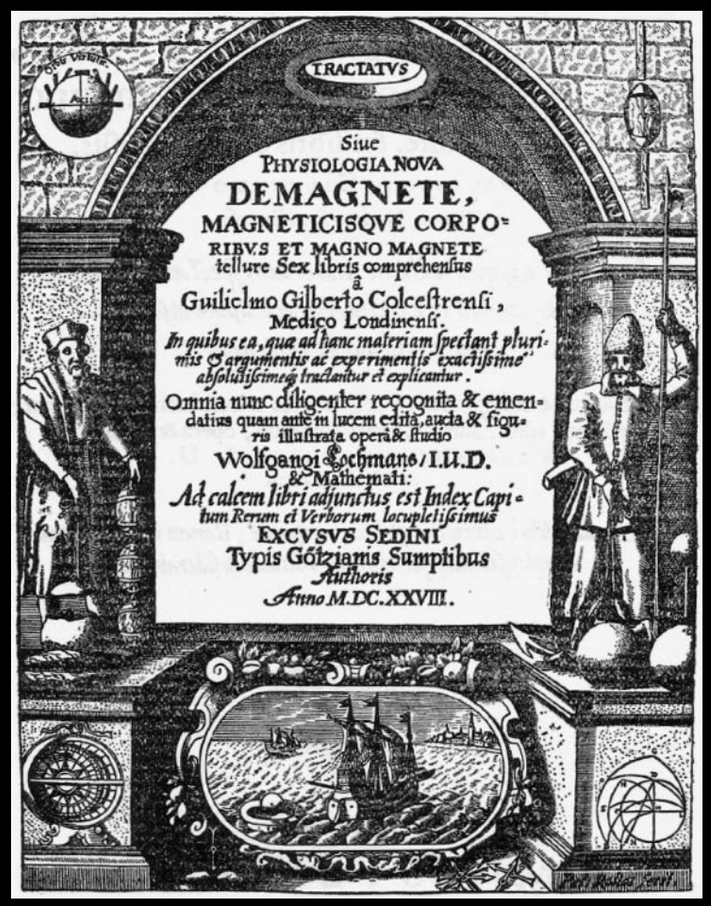
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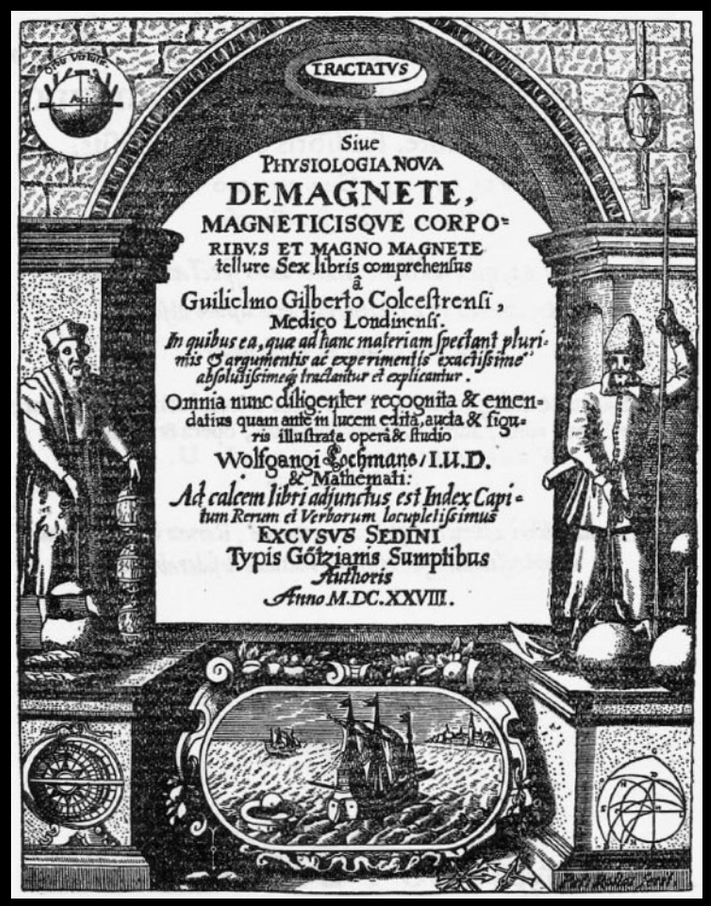
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"In thick weather, the effluvia are stifled, and the surface of the rubbed body is affected by the vaporous air, and the effluvia are stopped at their very origin."

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Francis Hauksbee

Draper, instrument maker, laboratory assistant

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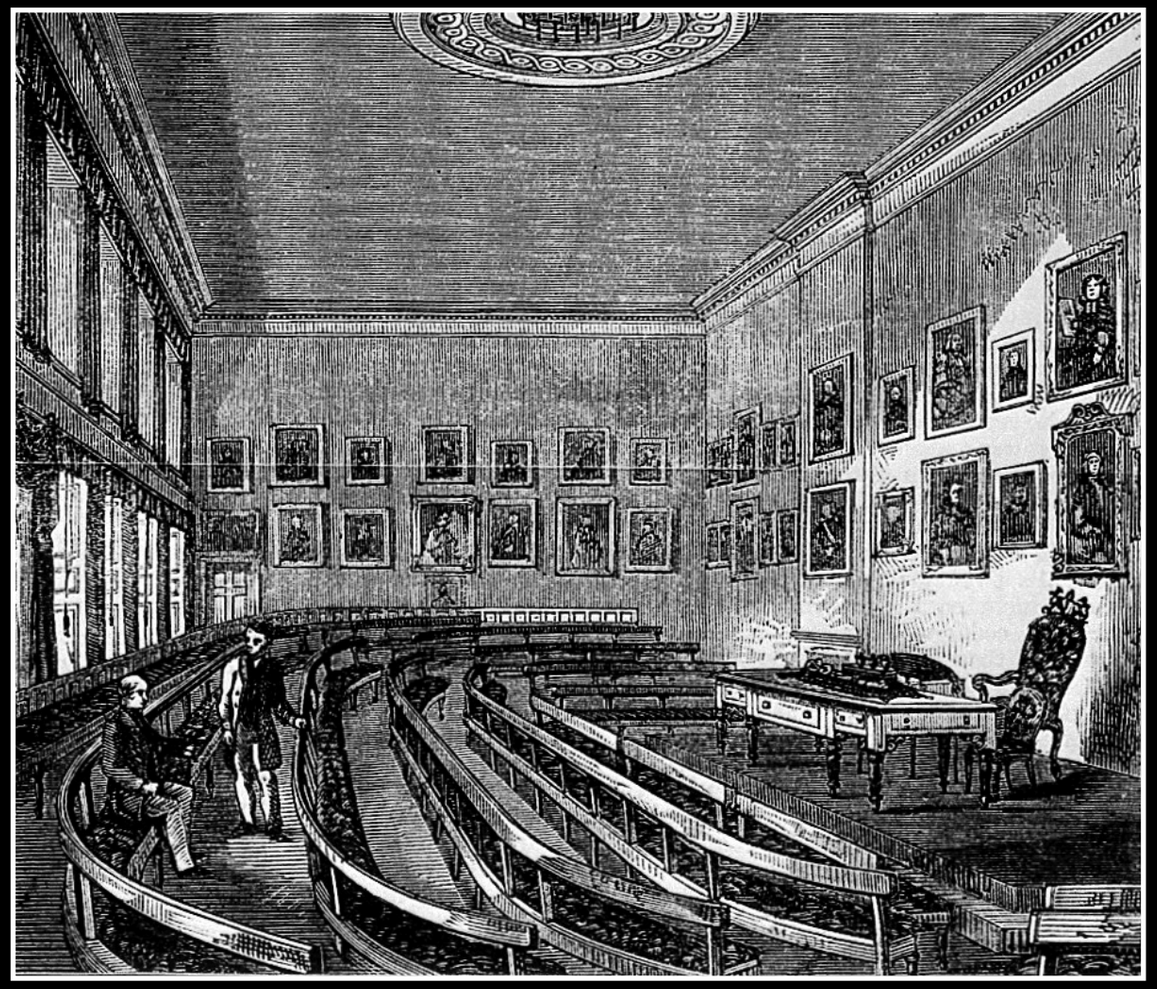

Meeting room of *The Royal Society of London for Improving Natural Knowledge*

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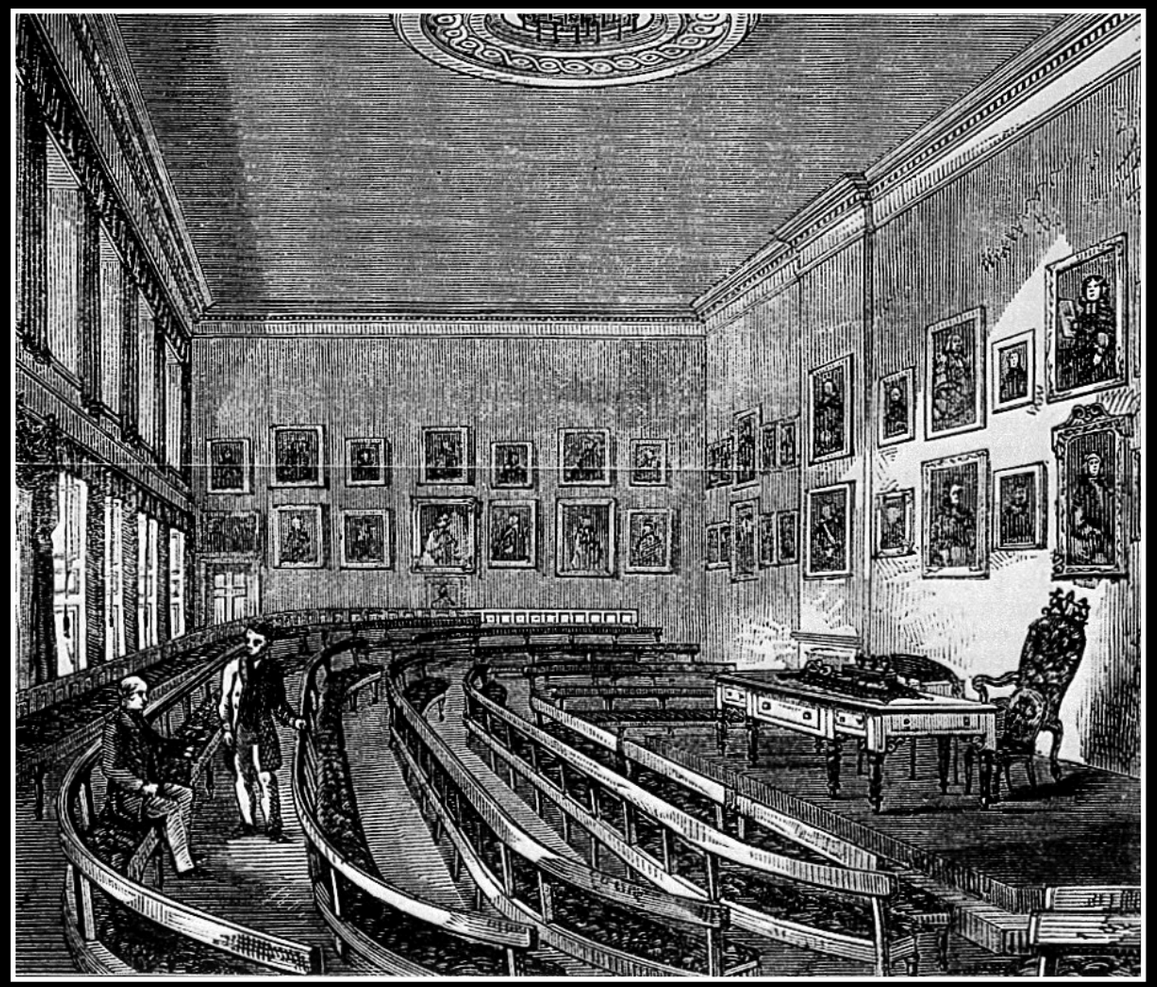

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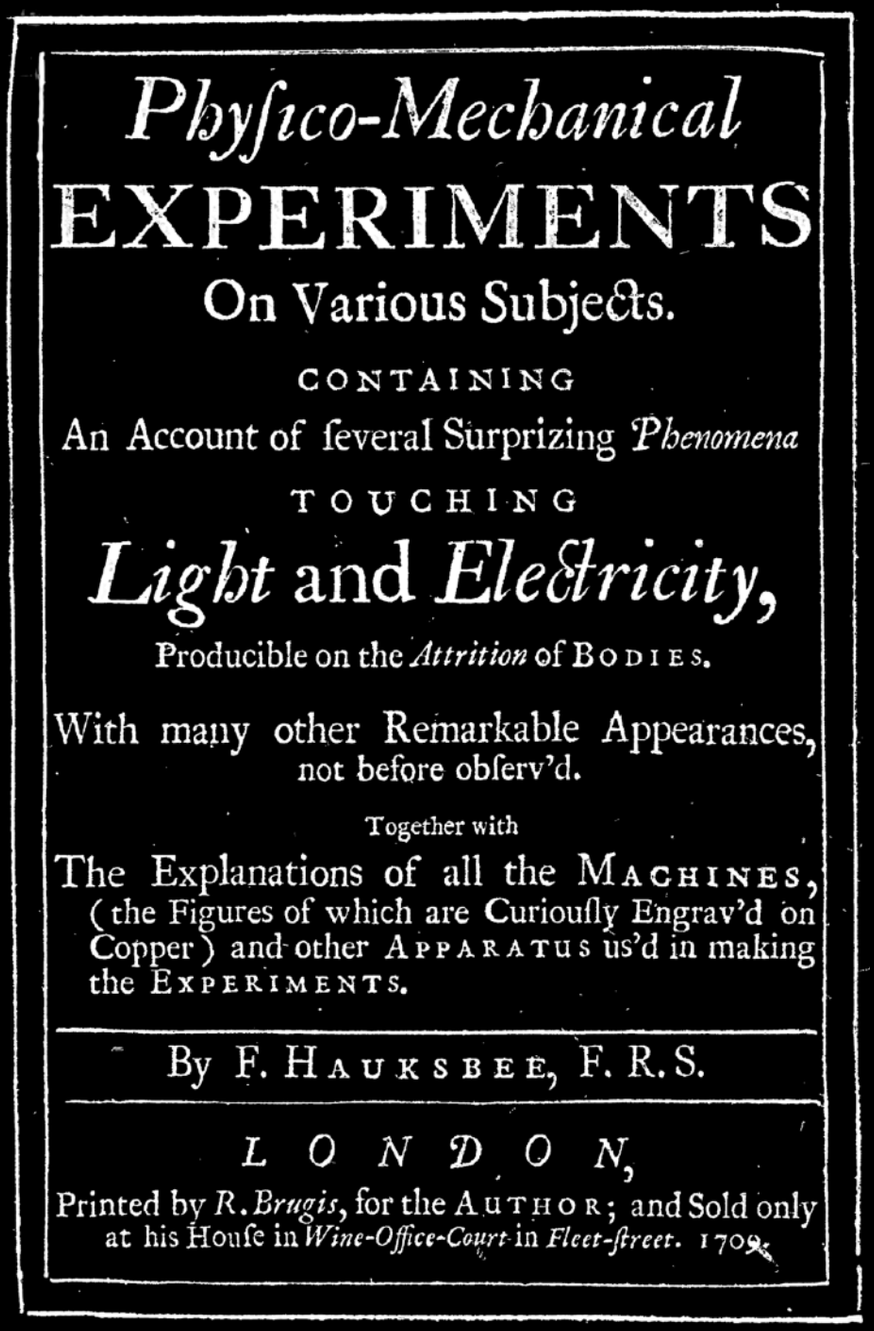

Phyſico-Mechanical
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On Various Subjects.

CONTAINING

An Account of ſeveral Surprizing *Phenomena*

TOUCHING

Light and *Electricity*,

Producible on the *Attrition* of BODIES.

With many other Remarkable Appearances, not before obſerv'd.

Together with

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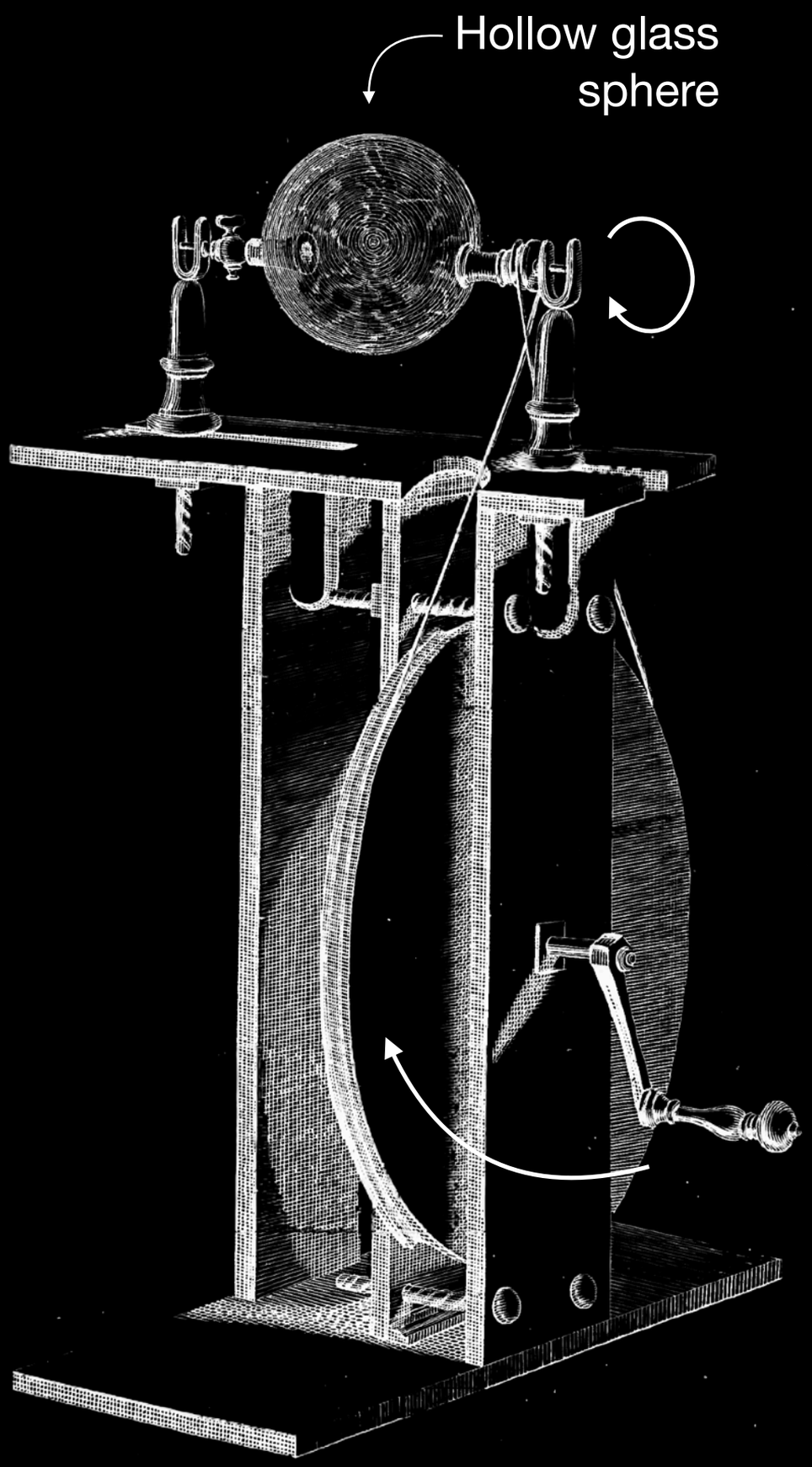
By F. HAUKSBEE, F. R. S.

LONDON,

Printed by *R. Brugis*, for the AUTHOR; and Sold only at his Houſe in *Wine-Office-Court* in *Fleet-ſtreet*. 1709.

Collected experiments, published 1709

Hauksbee’s experiments



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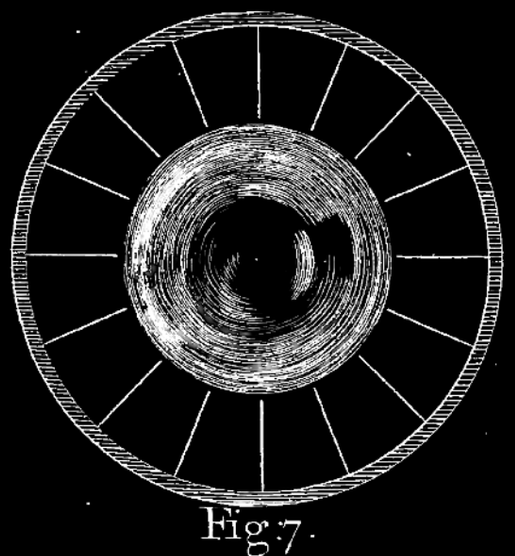
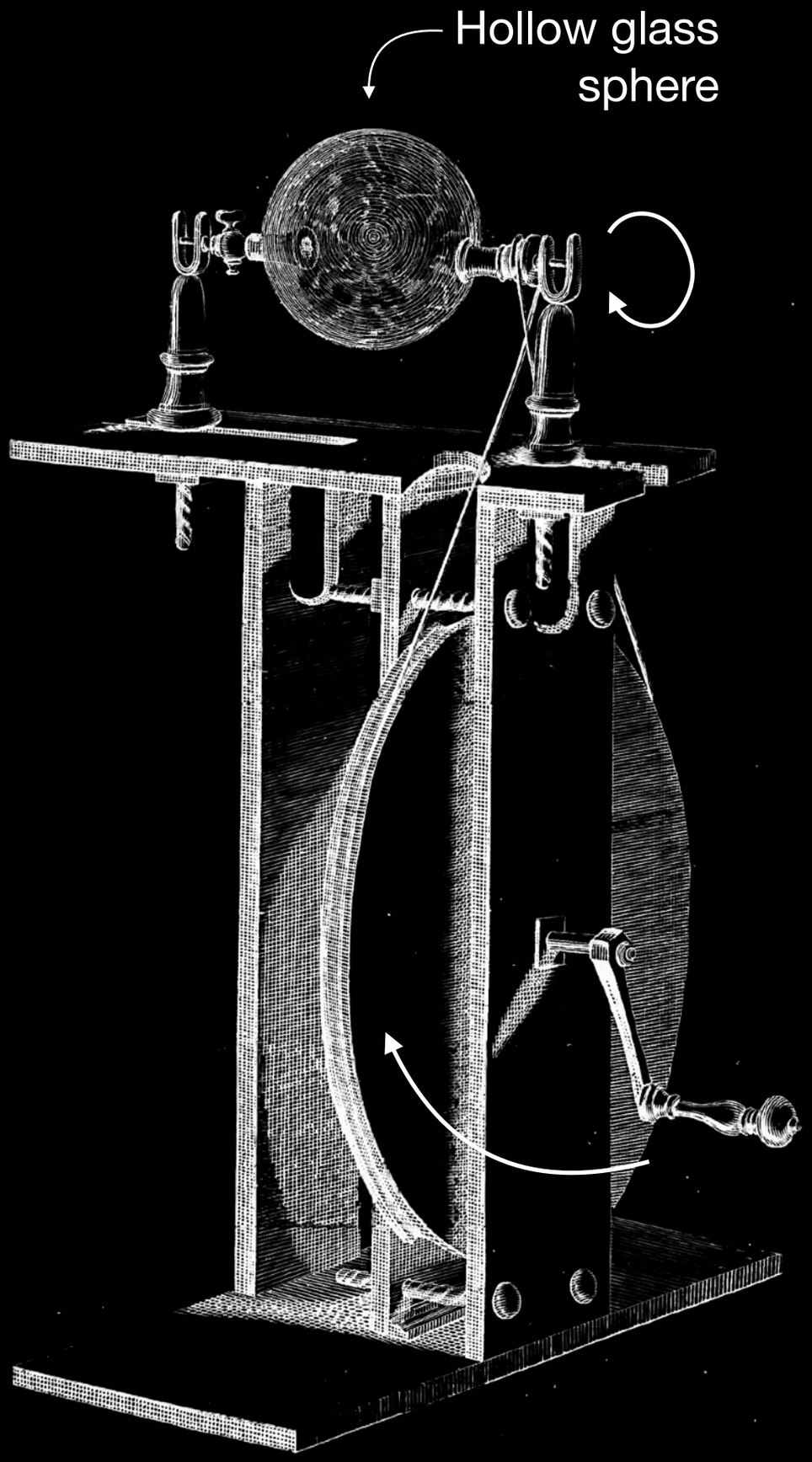


"The woolen threads have been laid hold of by the Effluvia; then, tho' the glass had no motion at all, yet would all the threads continue in their straight directed posture […]"



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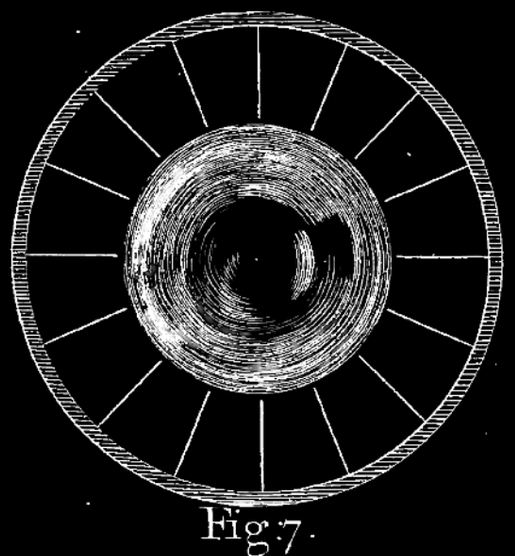

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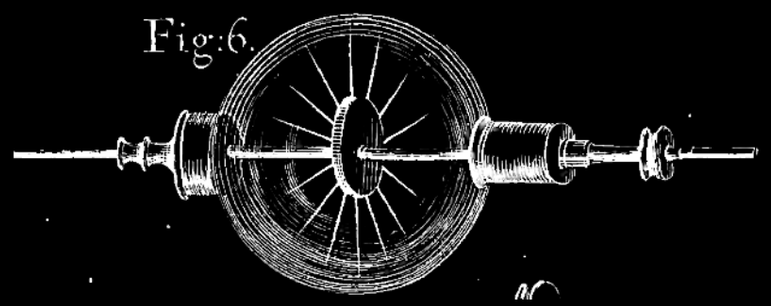
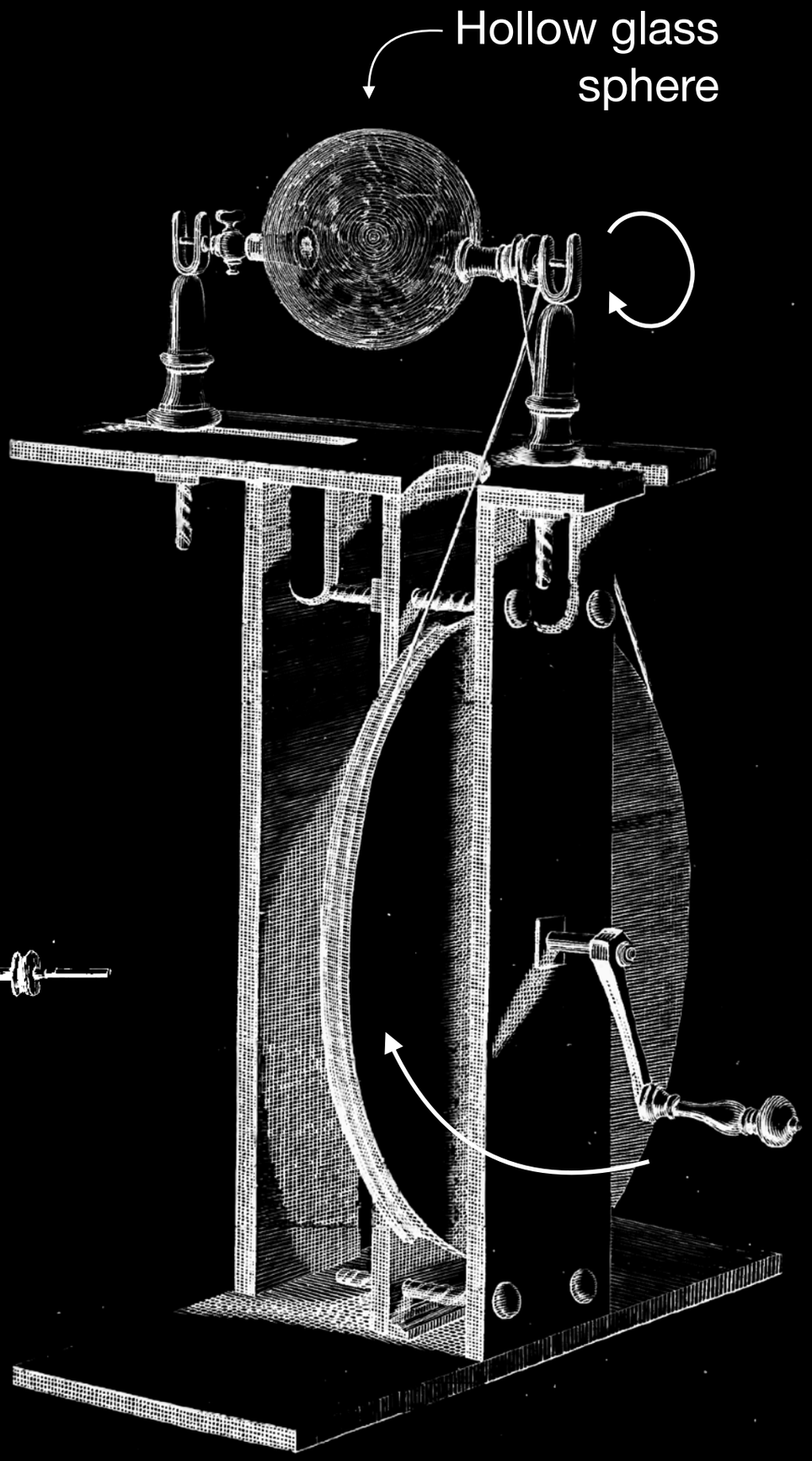
"The threads here issued like rays, from a center outwards."





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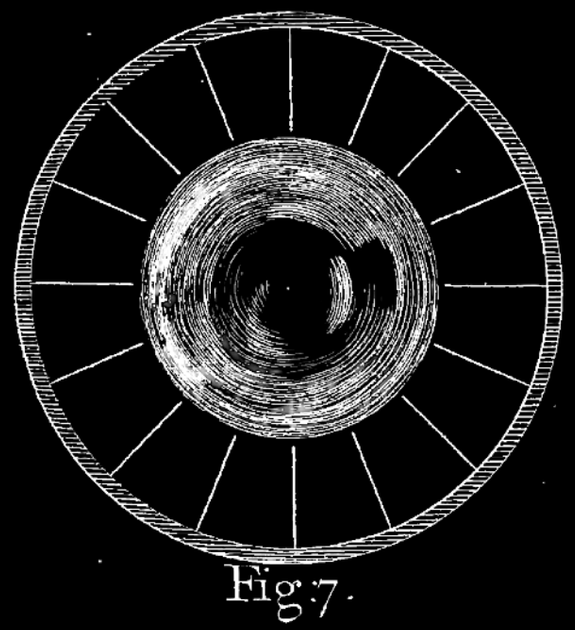
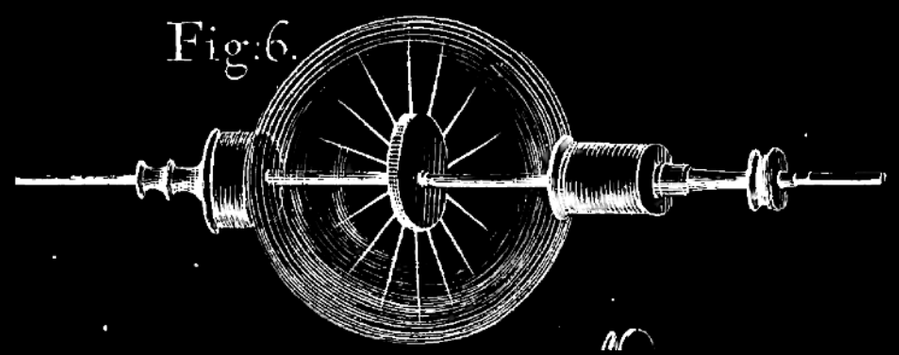


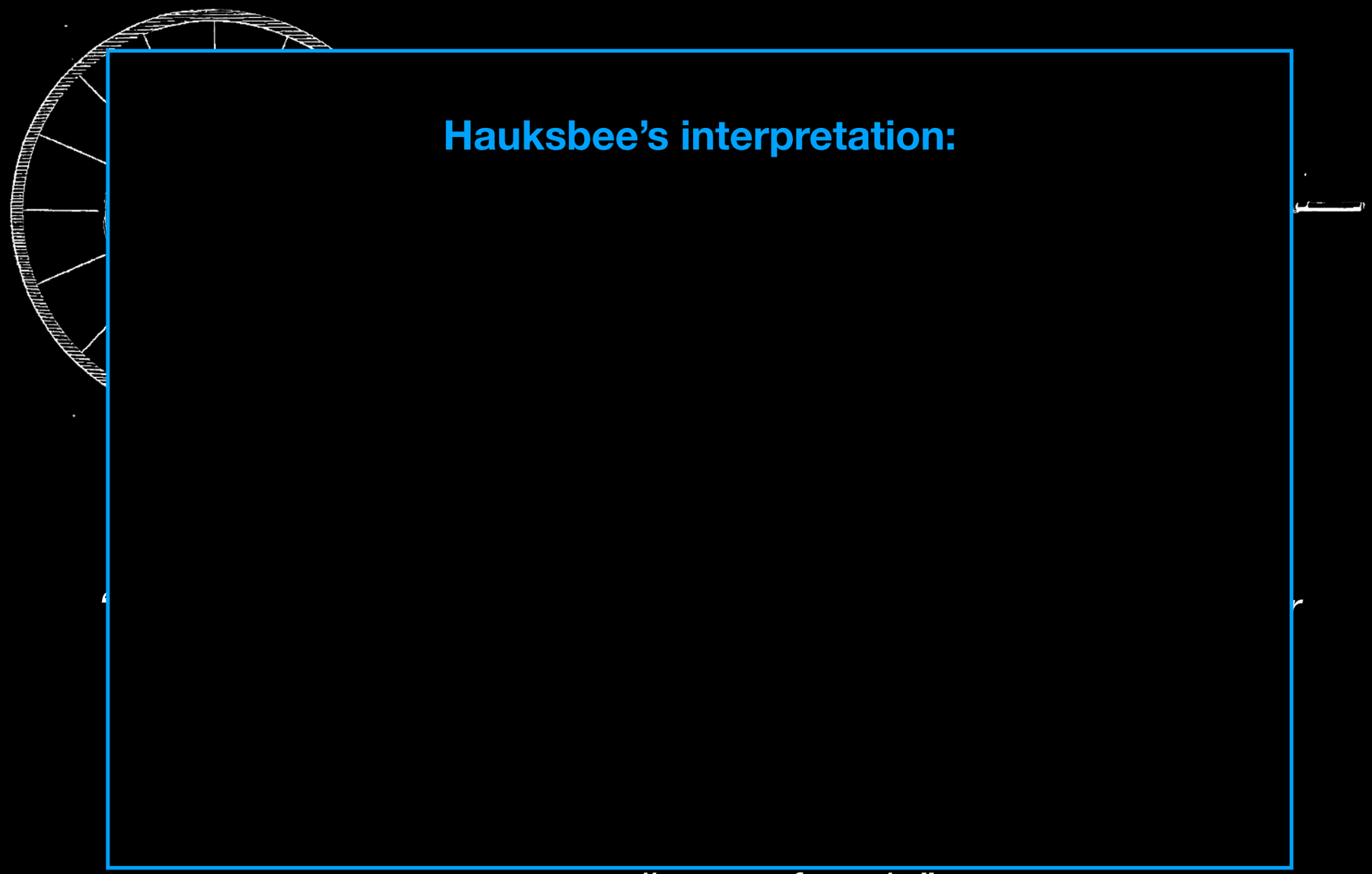


"The threads avoided the finger when it approach'd very near their extremities."

"It seems very much to resemble or emulate a solid, since motion may be given to a body by pushing the Effluvia at some distance from it."

"Electric spiderweb"

Hauksbee’s experiments



Hauksbee’s interpretation:

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“Electric spiderweb”

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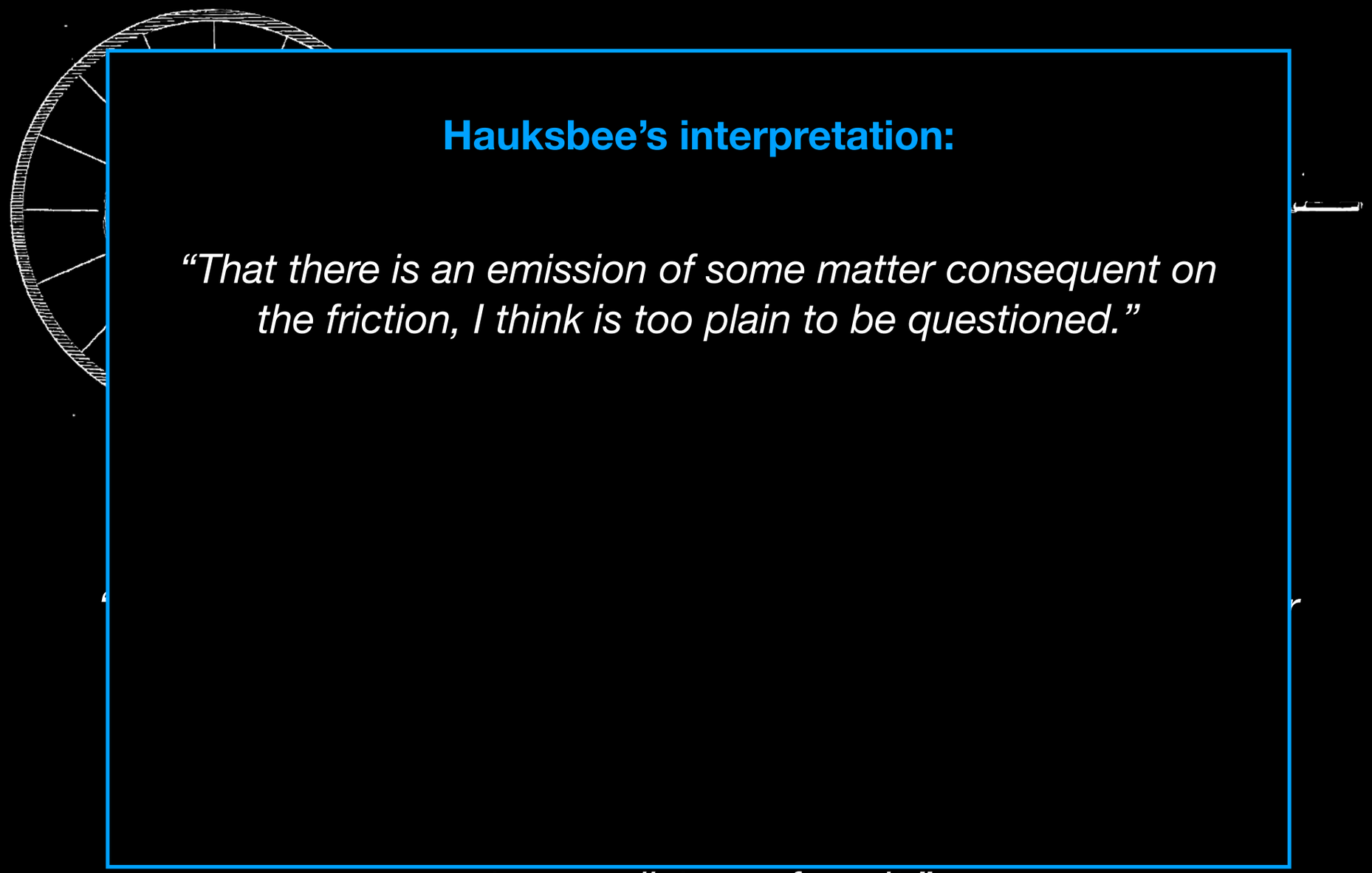

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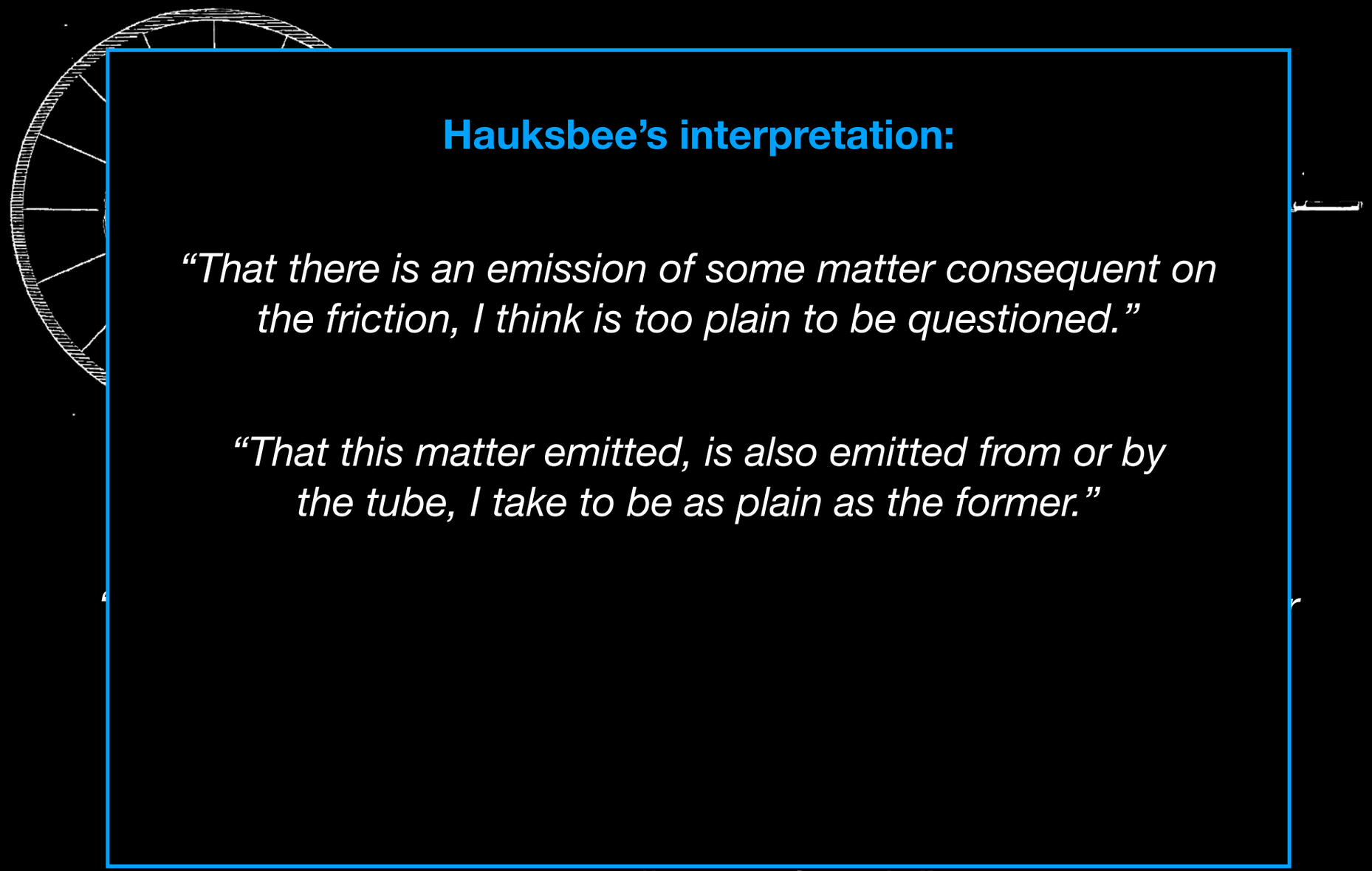

Hauksbee’s interpretation:

“That there is an emission of some matter consequent on the friction, I think is too plain to be questioned.”

“That this matter emitted, is also emitted from or by the tube, I take to be as plain as the former.”

at some distance from it.”

“Electric spiderweb”

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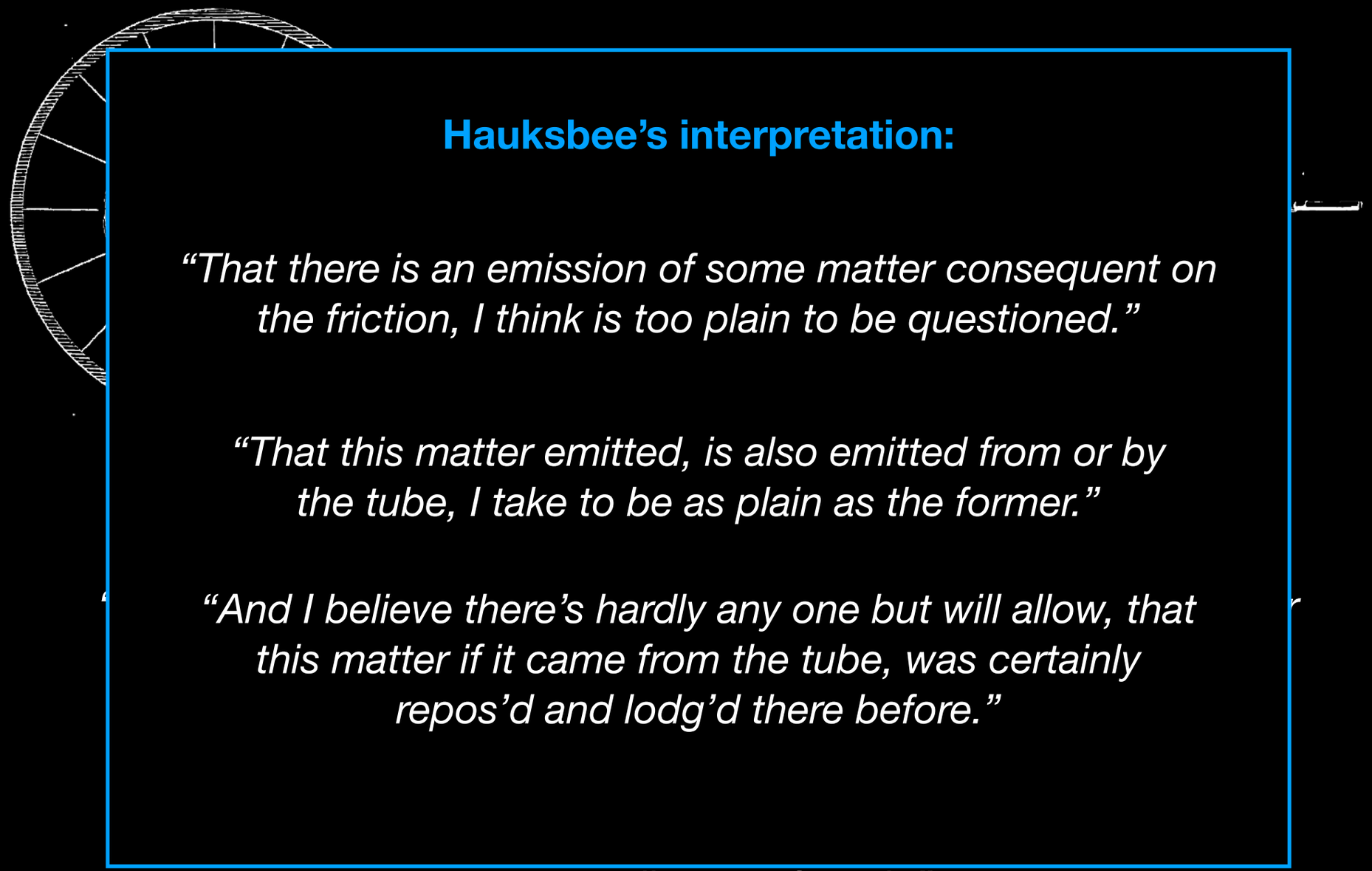

Hauksbee’s interpretation:

“That there is an emission of some matter consequent on the friction, I think is too plain to be questioned.”

“That this matter emitted, is also emitted from or by the tube, I take to be as plain as the former.”

“And I believe there’s hardly any one but will allow, that this matter if it came from the tube, was certainly repos’d and lodg’d there before.”

at some distance from it.”

“Electric spiderweb”

Stephen Gray

Cloth-dyer, hobby astronomer

John Flamsteed,
Astronomer Royal at Greenwich

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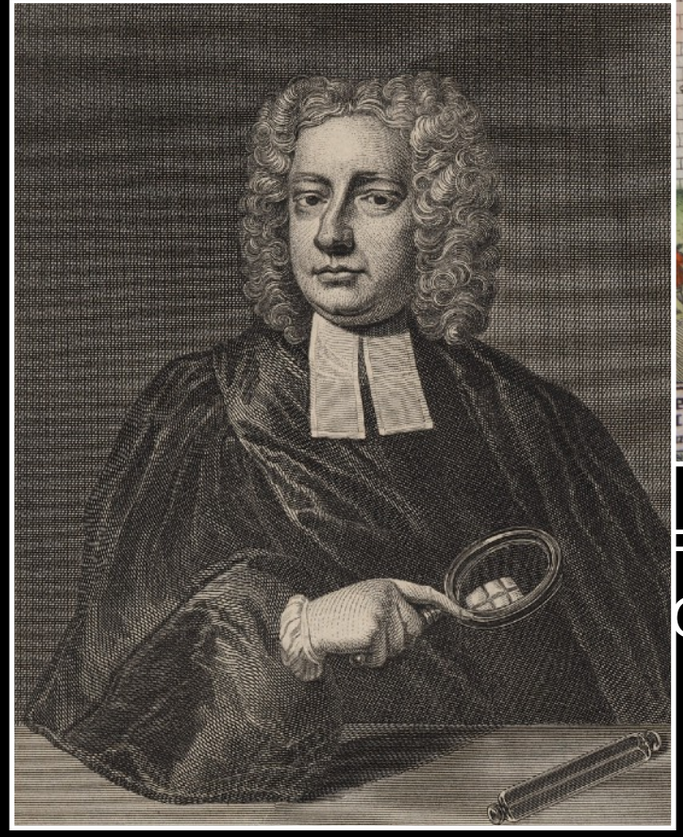
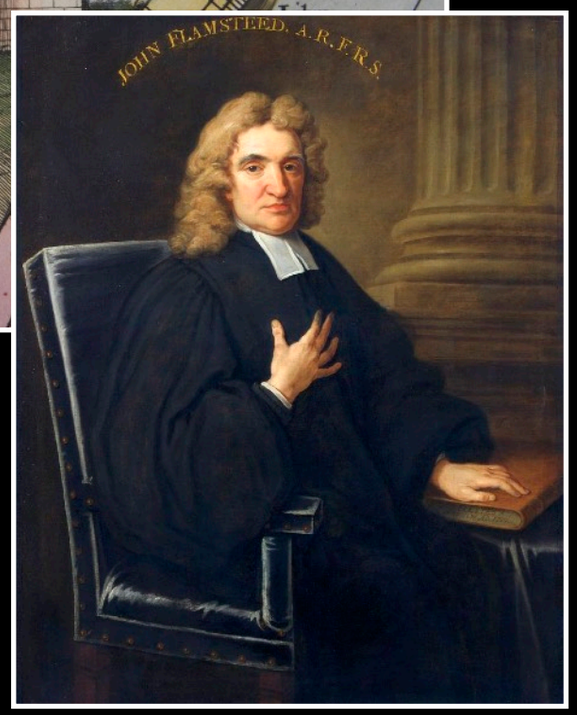
John Desaguliers,
Curator of Experiments
at Royal Society



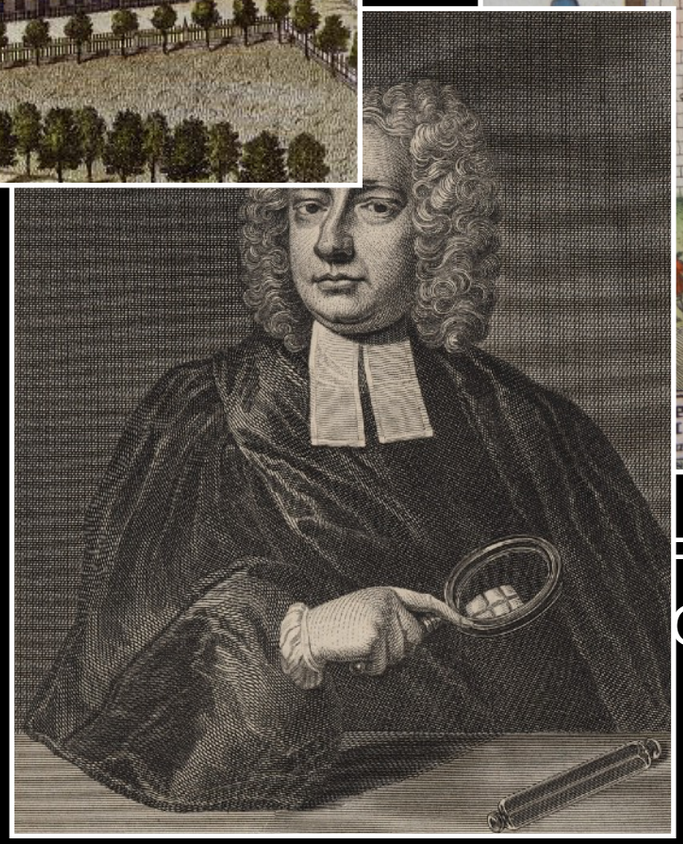
Flamsteed,
Greenwich



Stephen Gray

Cloth-dyer, hobby astronomer

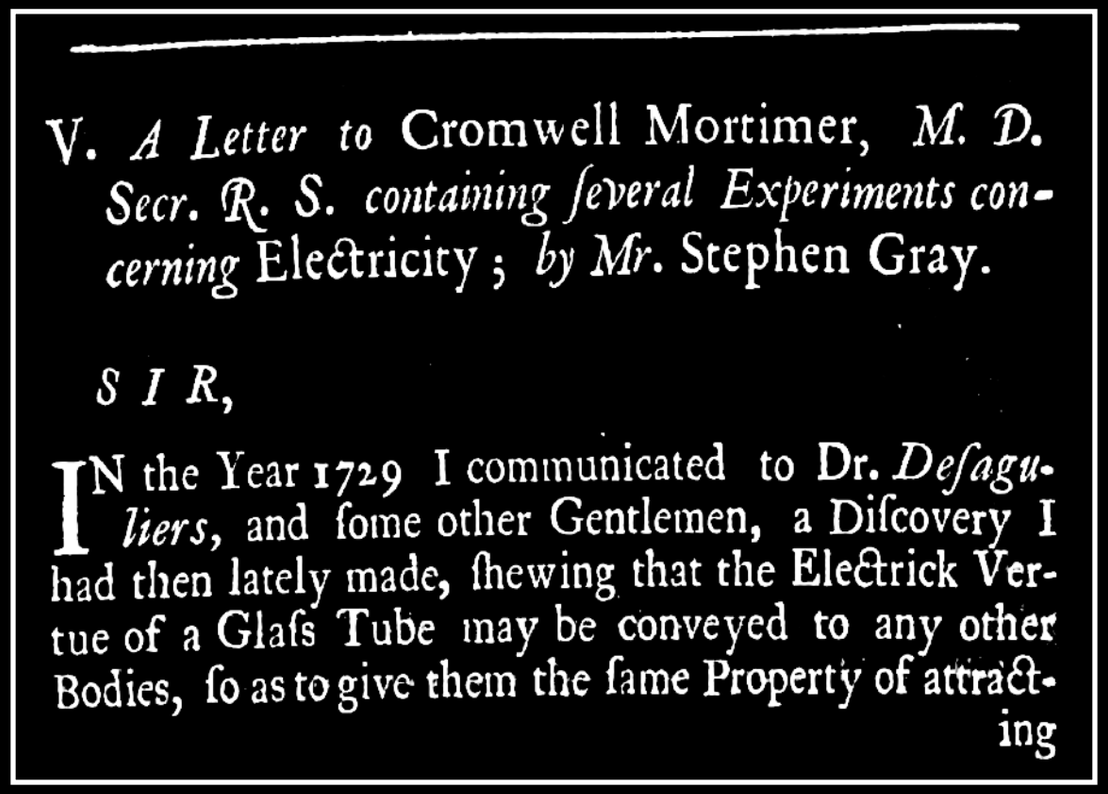
Charterhouse



John Desaguliers,
Curator of Experiments
at Royal Society

Flamsteed,
Greenwich

The discovery of conductivity (1729)



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. *Deſaguliers*, and ſome other Gentlemen, a Diſcovery I had then lately made, ſhewing that the Electrick Vertue of a Glaſs Tube may be conveyed to any other Bodies, ſo as to give them the ſame Property of attracting

His first try: "*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 success.*"

"I then resolved to procure me a large flint-glass tube, to see if I could make any further discovery with it […]"

Gray’s glass tube

Gray’s glass tube

“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. To each end I fitted a cork, to keep the dust out when the tube was not in use.”

Gray’s glass tube

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“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, but could perceive no sensible difference.”

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“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, but could perceive no sensible difference.”

“But upon holding a down feather over against the flat end of the cork, which attracted many times together; at which I was much surprised, and concluded that there was certainly an attractive vertue communicated to the cork by the excited cork.”

There is no going back

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“Having by me an ivory ball of about one inch diameter, with a hole through it, this I fixed upon a fir stick about four inches long, thrusting the other end into the cork,

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“Having by me an ivory ball of about one inch 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 the feather with more vigor than the cork had done.

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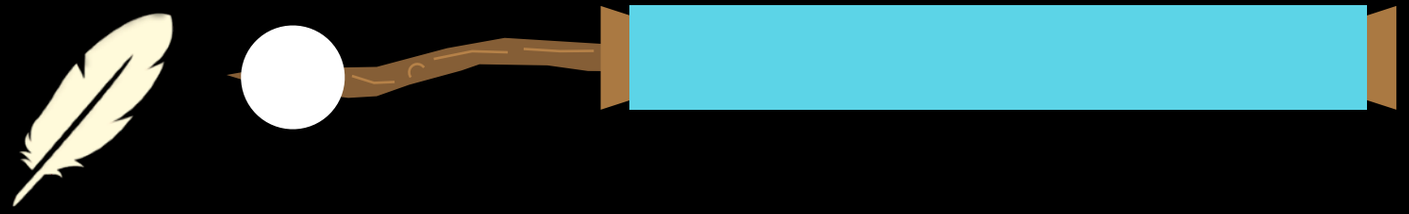

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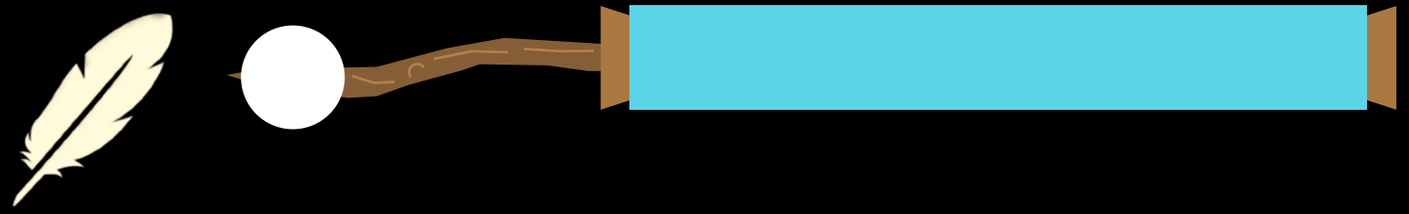
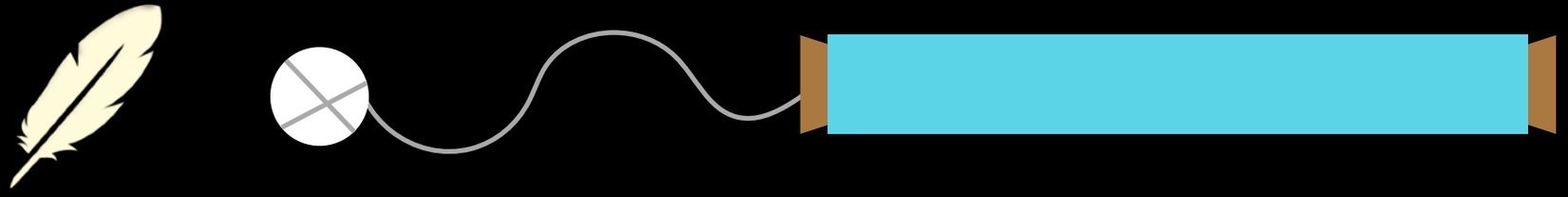


“I then fixed the ball on longer sticks, first upon one of eight inches, and afterwards upon one of twenty-four inches long, and found the effect the same.”

There is no going back

“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.”



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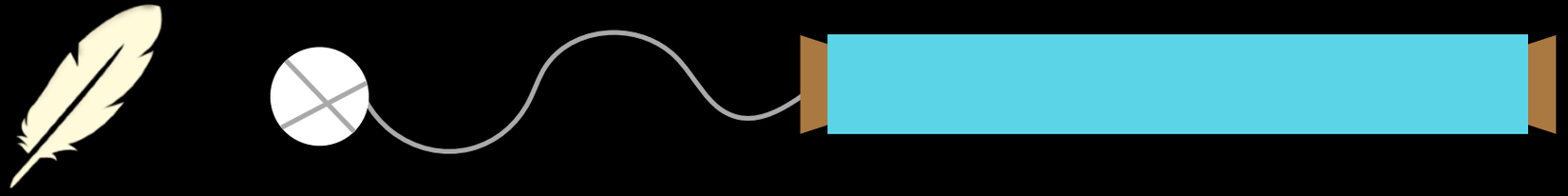

“I then went on to see upon what other bodies the tube would have the same effect, beginning with the metals, first in small pieces, as with a Shilling, a Half-Penny; then with larger quantities of metal.”

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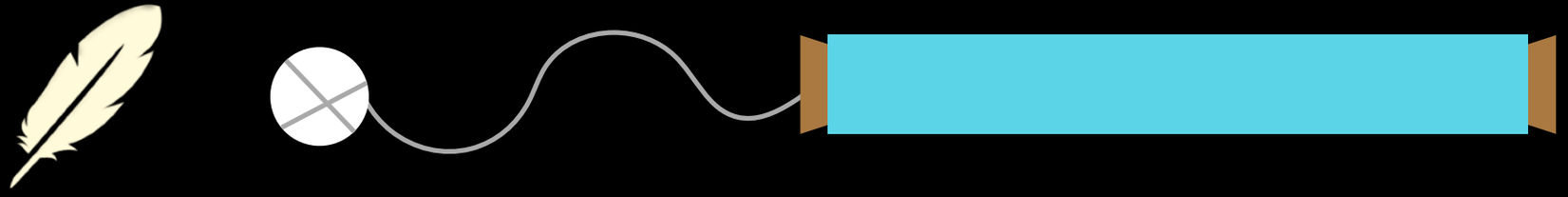

“I then went on to see upon what other bodies the tube would have the same effect, beginning with the metals, first in small pieces, as with a Shilling, a Half-Penny; then with larger quantities of metal.”

“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.”

Pushing further

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“[…] with several pieces of Spanish cane and fir sticks I 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 […]”

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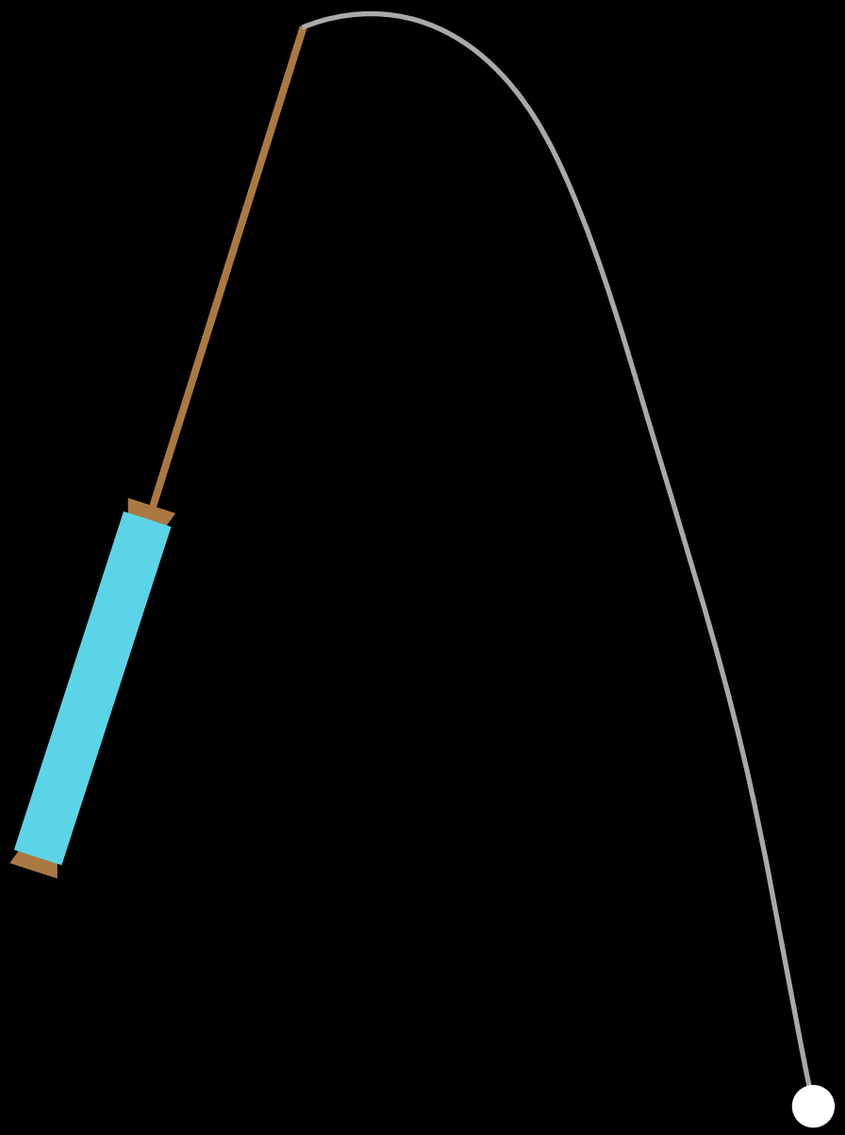
“[…] and found the attraction very nearly, if not altogether as strong, as when the ball was placed on shorter rods.”

“Thus far I proceeded before I went into the country, taking with me several glass canes, and such other materials I thought would be necessary, and could not well be procured there.”

The sky is the limit

“May 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 assistant below in the court.”

“Then the tube being excited as usual, the Electrick Vertue passed from the tube up the pole, and down the line to the ivory ball […]”

Horizontal transmission

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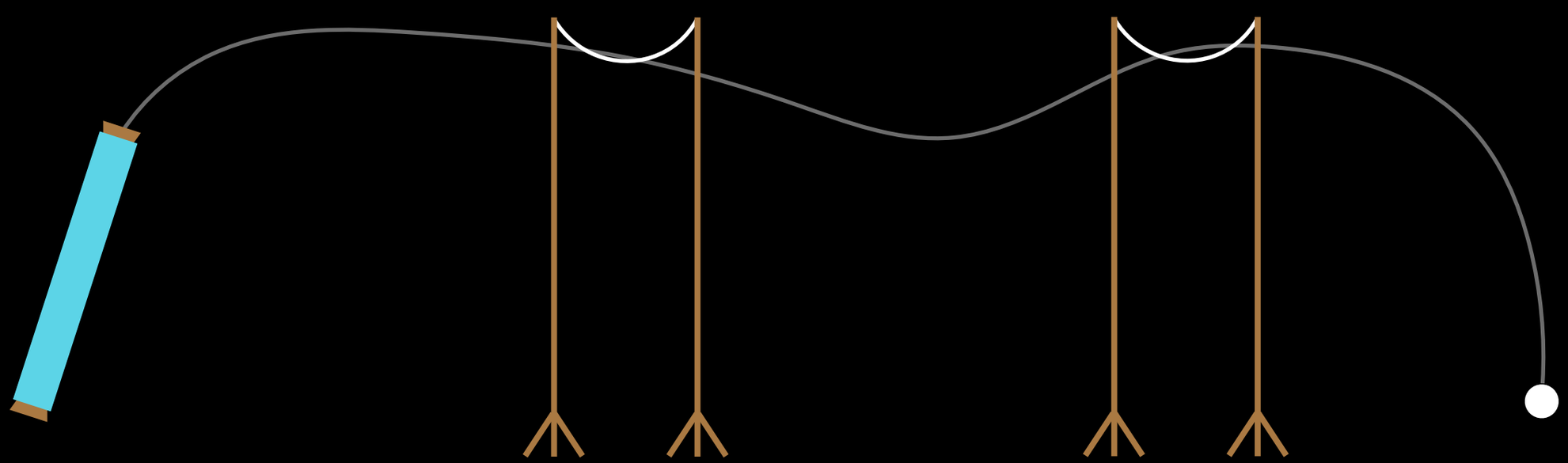

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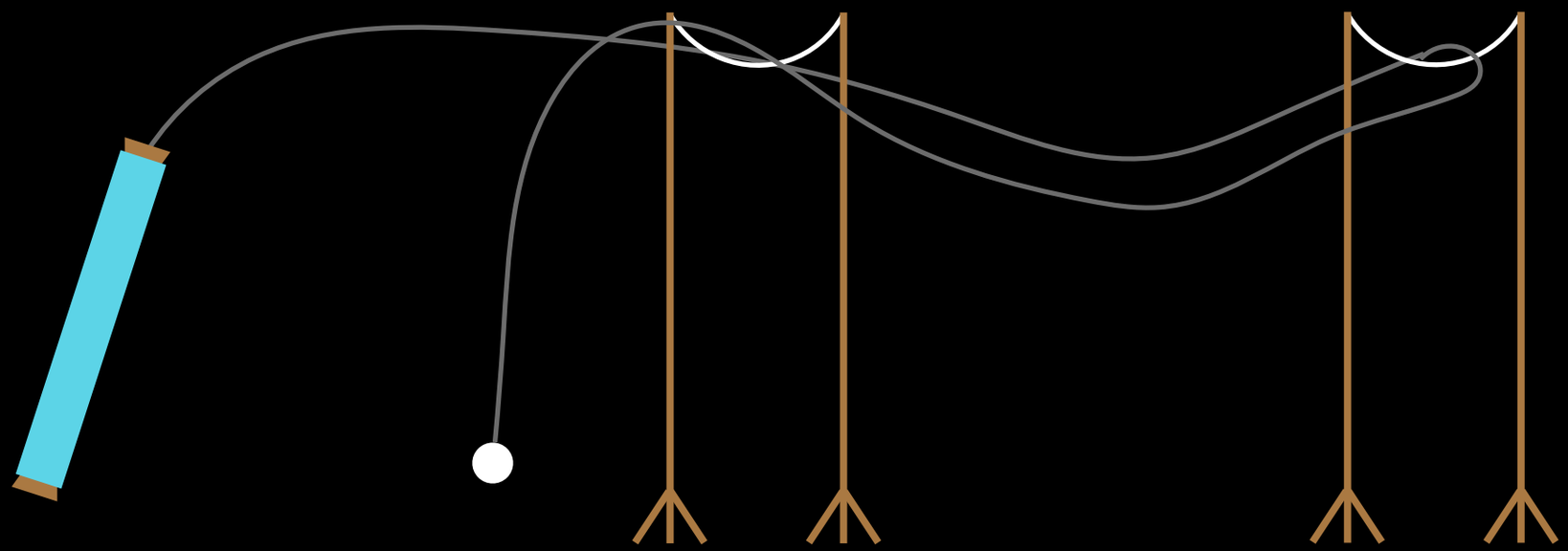
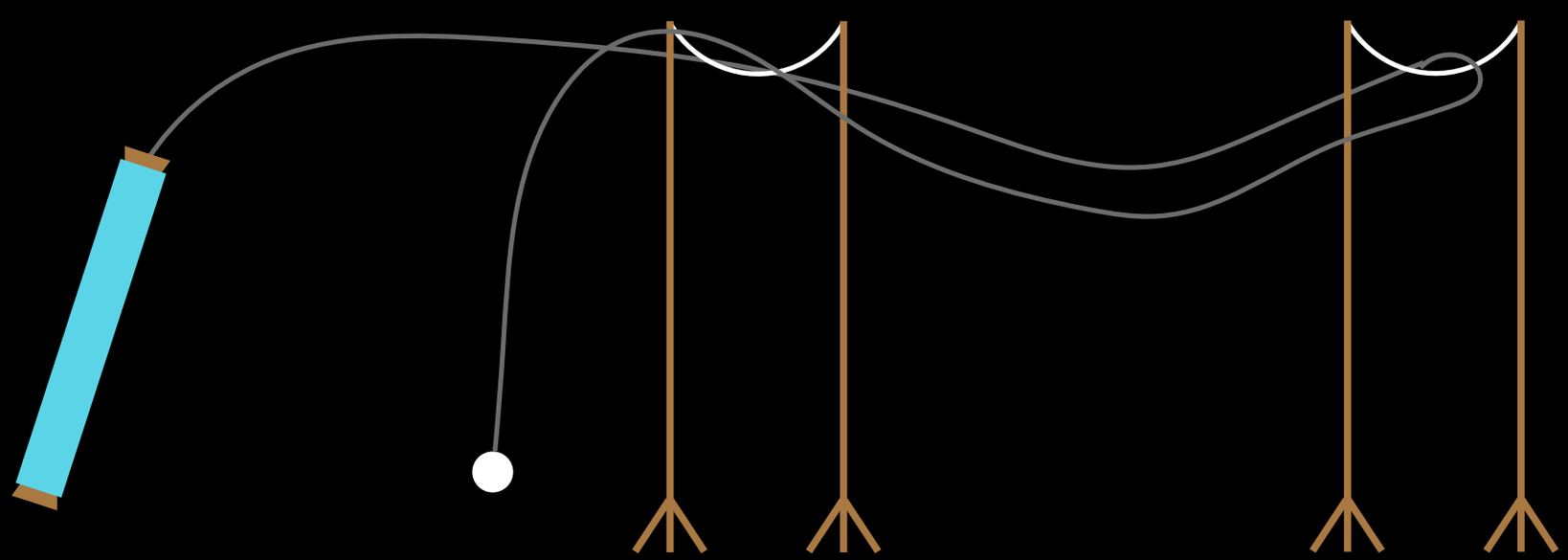


Horizontal transmission

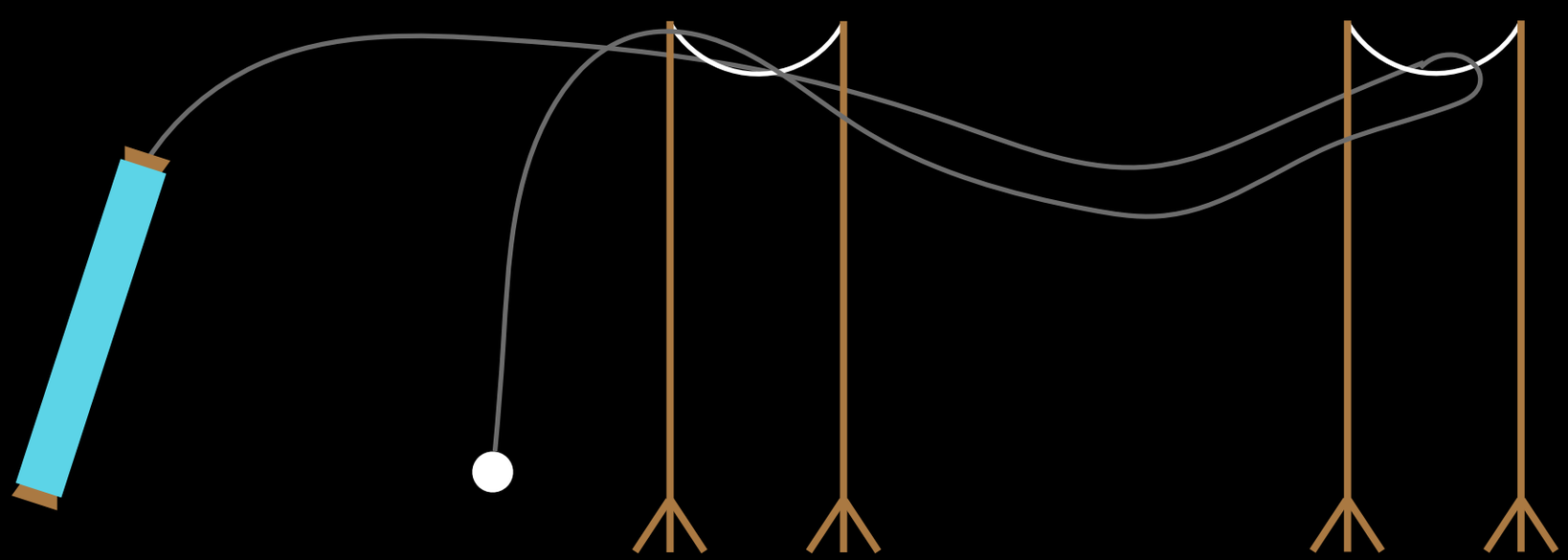
“We then proceeded farther, by adding so much more line as would make a return to the other end of the barn; the whole length of the line being now 293 feet.”



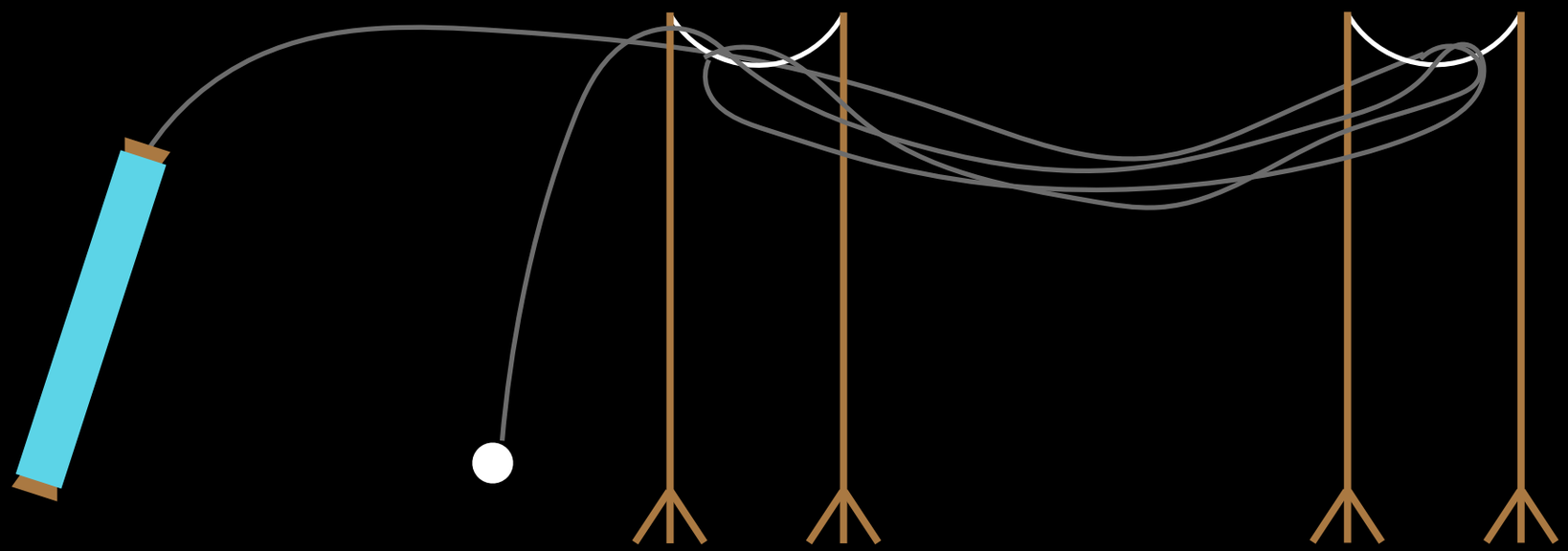
Horizontal transmission

“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 much lengthened, we found no perceivable difference in the attraction.”



The crucial discovery



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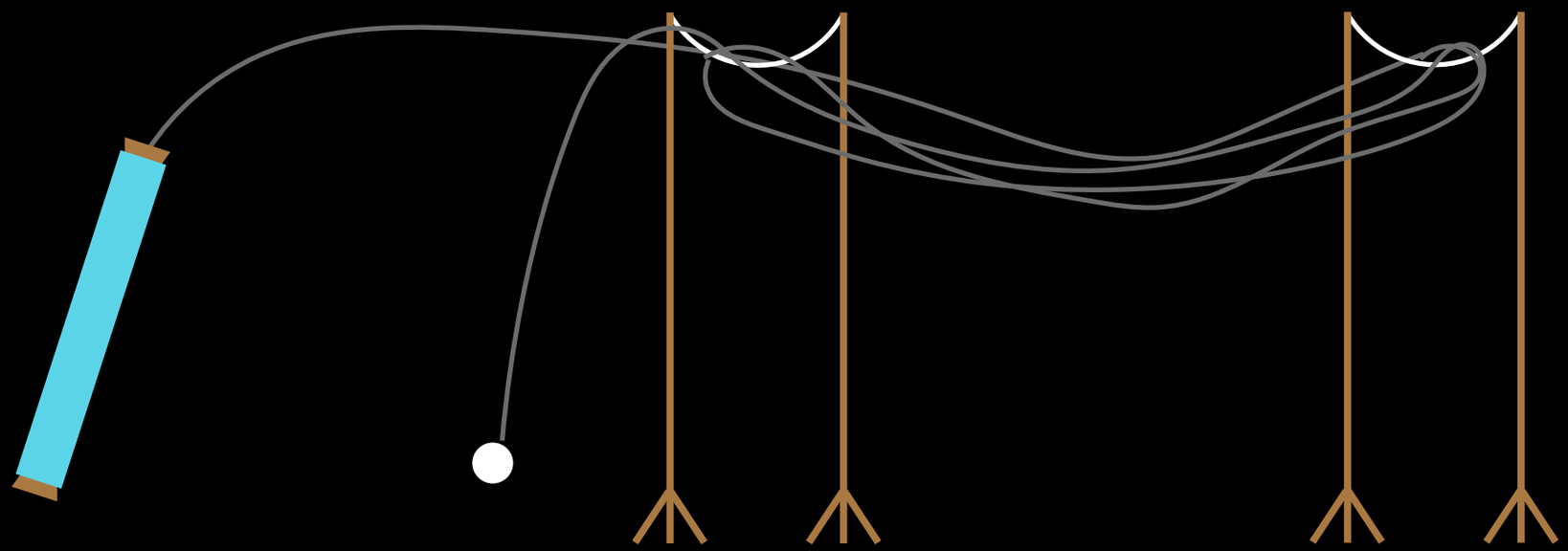
“This encouraged us to add another return; but upon beginning to rub the tube, our silk lines broke, being not strong enough to bear the weight of the line.”



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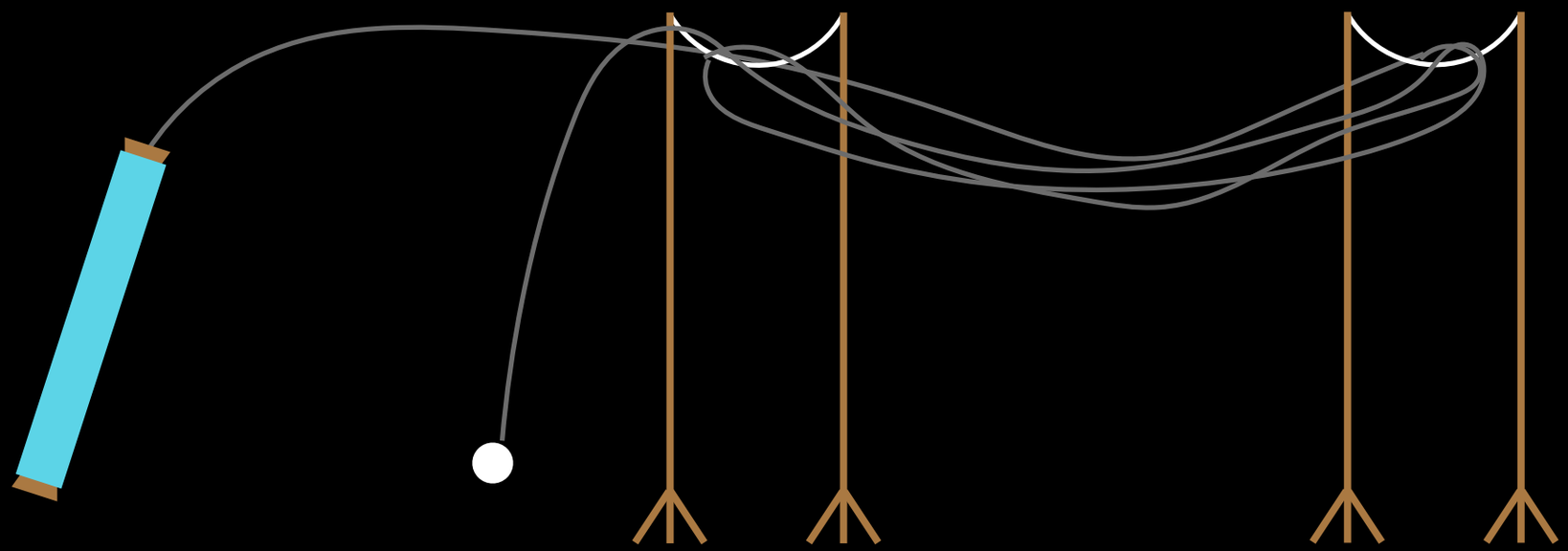
“This encouraged us to add another return; but upon beginning to rub the tube, our silk lines broke, being not strong enough to bear the weight of the line.”

“Instead of the silk, we put up brass wire. 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.”



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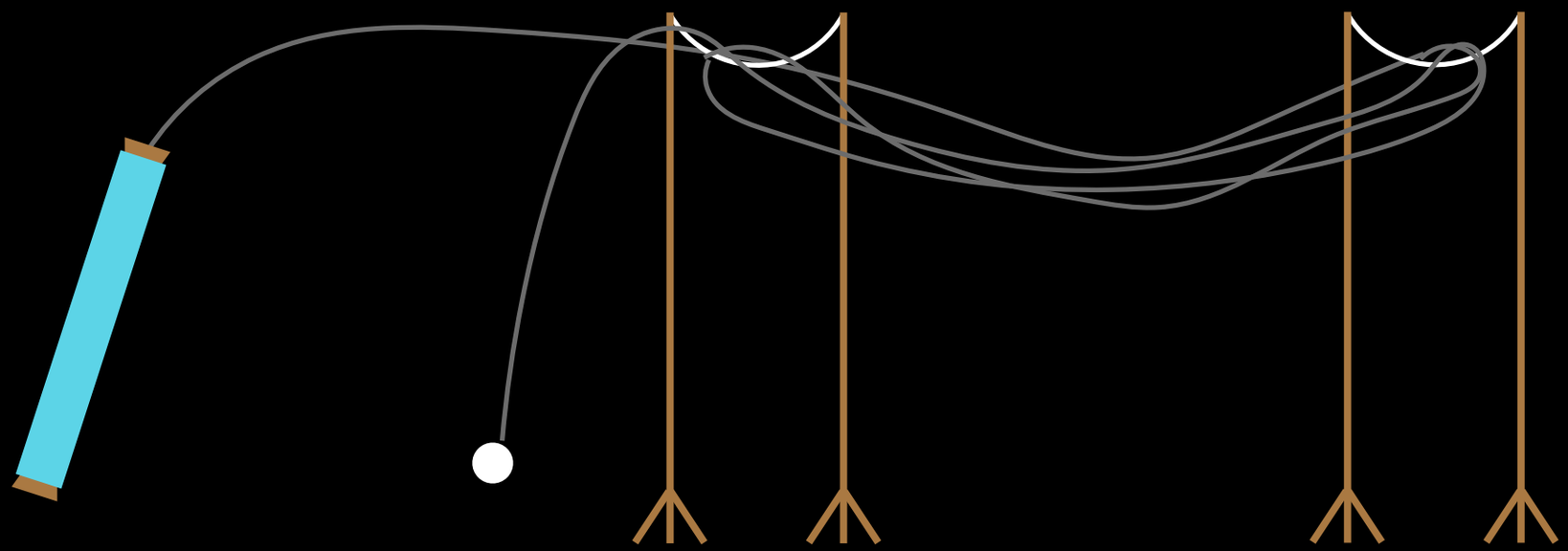

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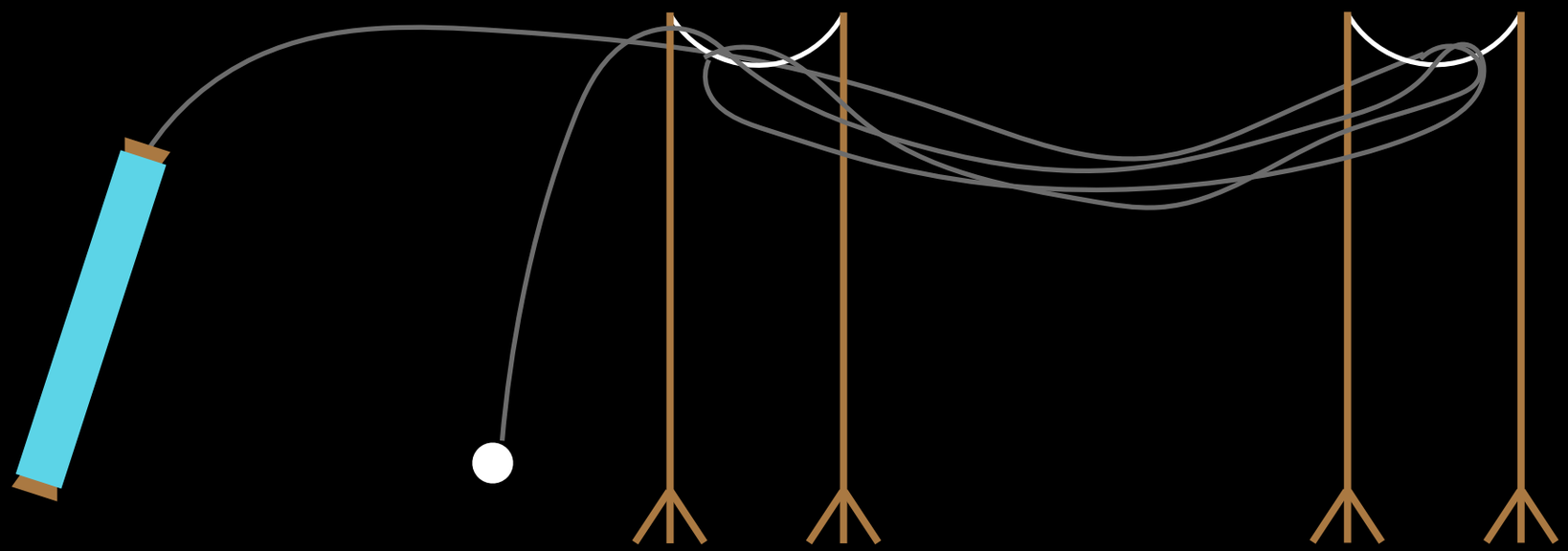

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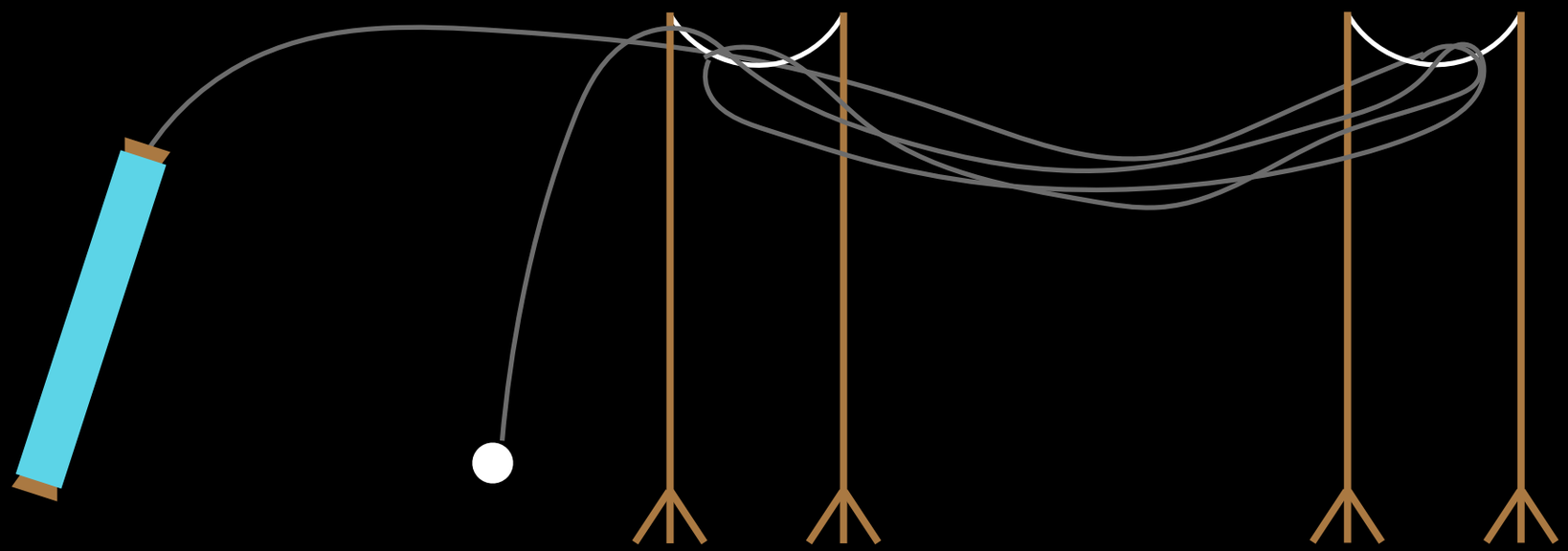

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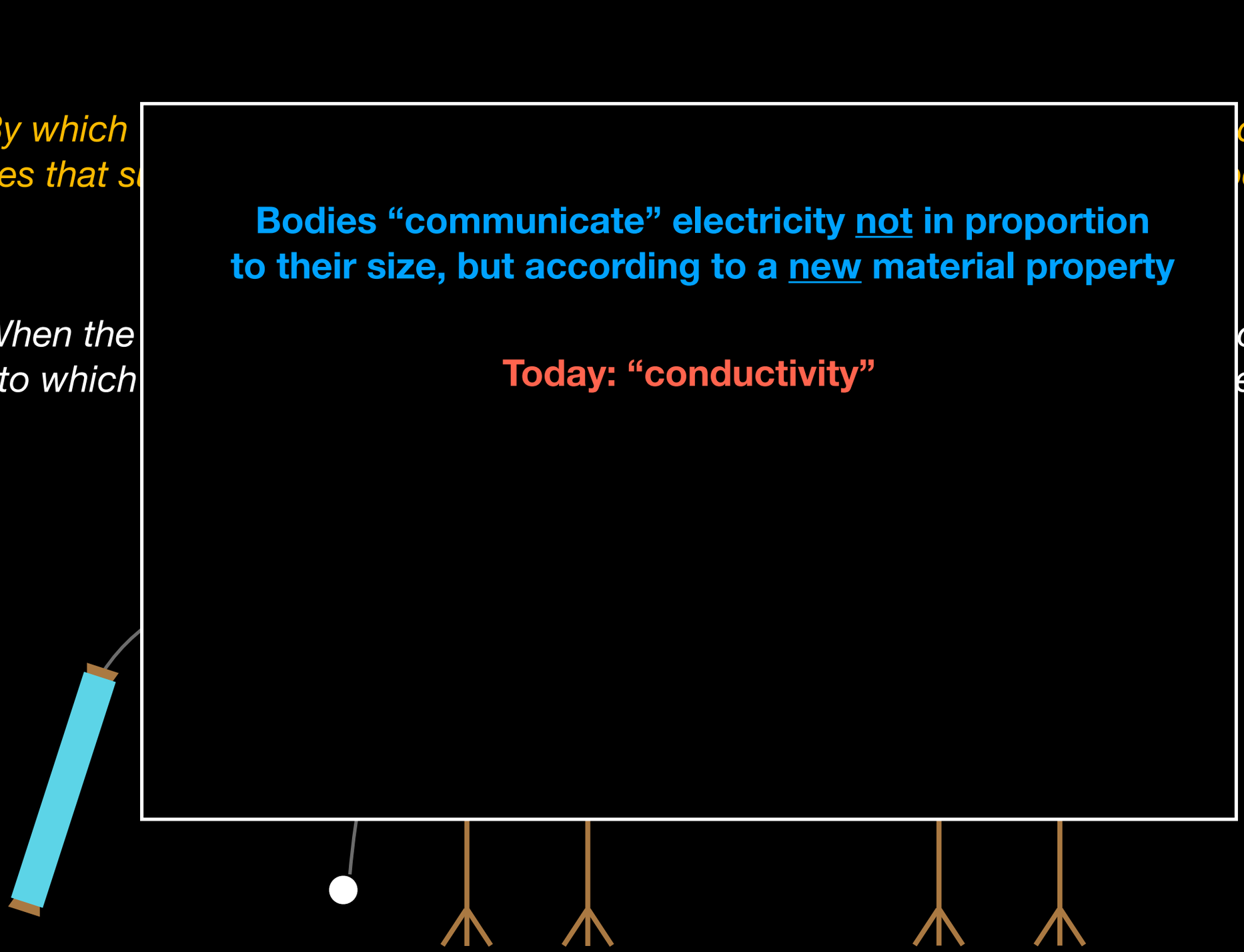
Bodies "communicate" electricity not in proportion to their size, but according to a new material property

Today: "conductivity"



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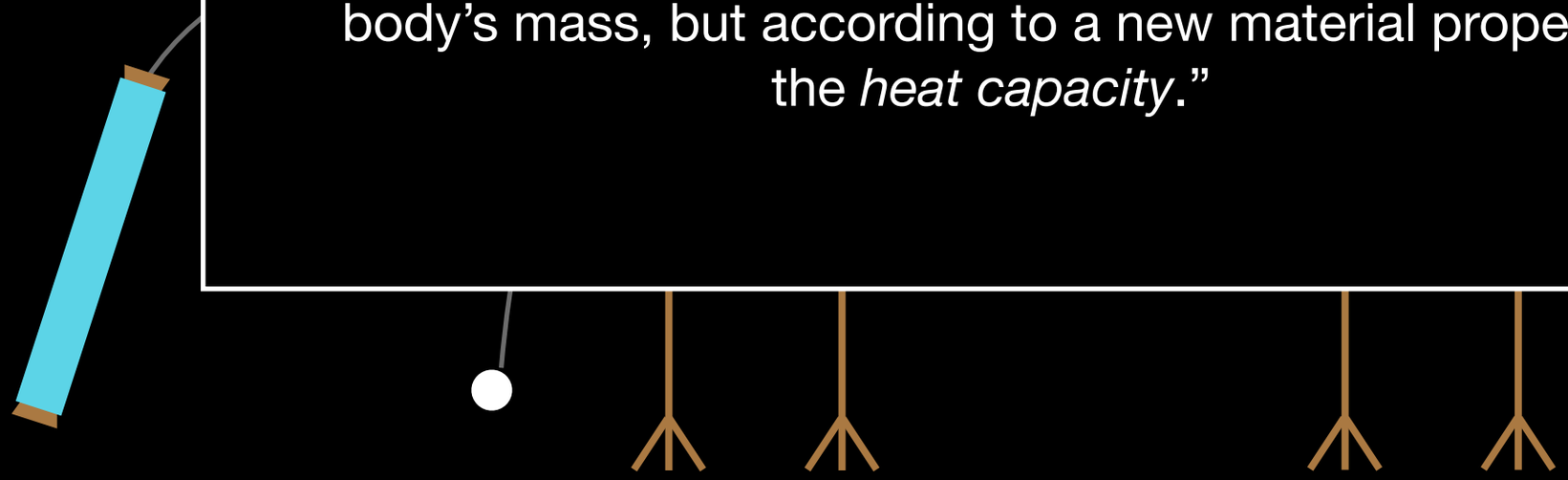
Joseph Black: "Heat is not absorbed in proportion to a body's mass, but according to a new material property, the *heat capacity*."



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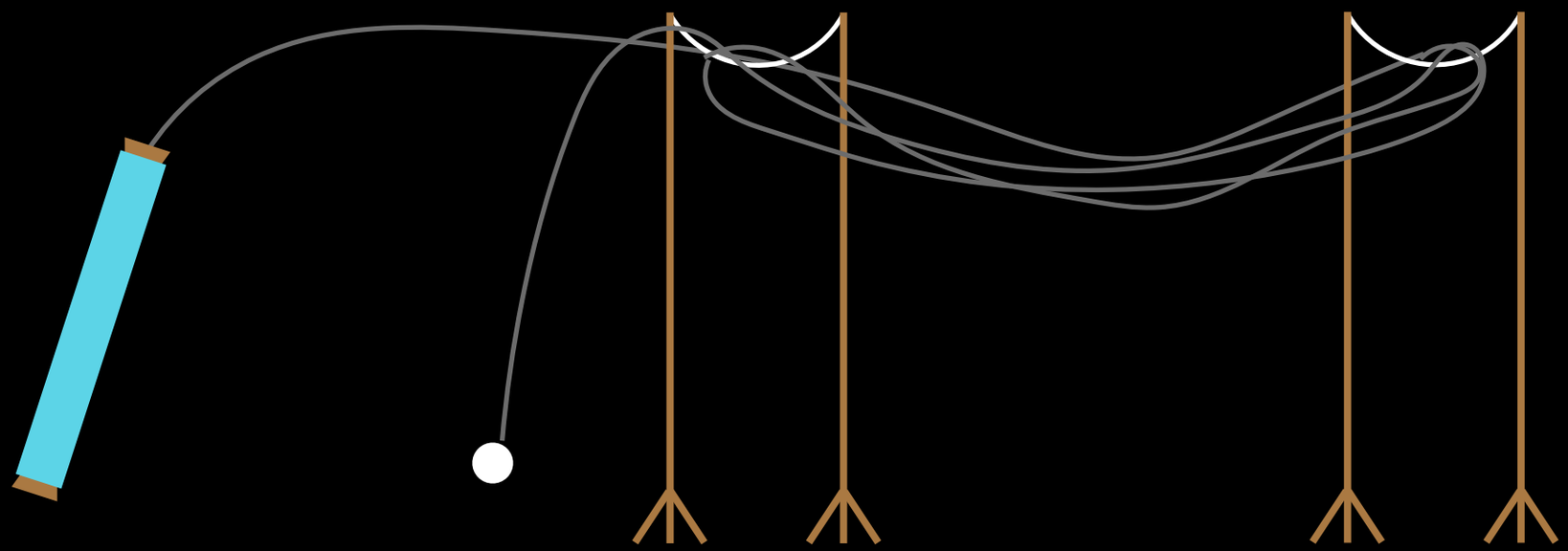

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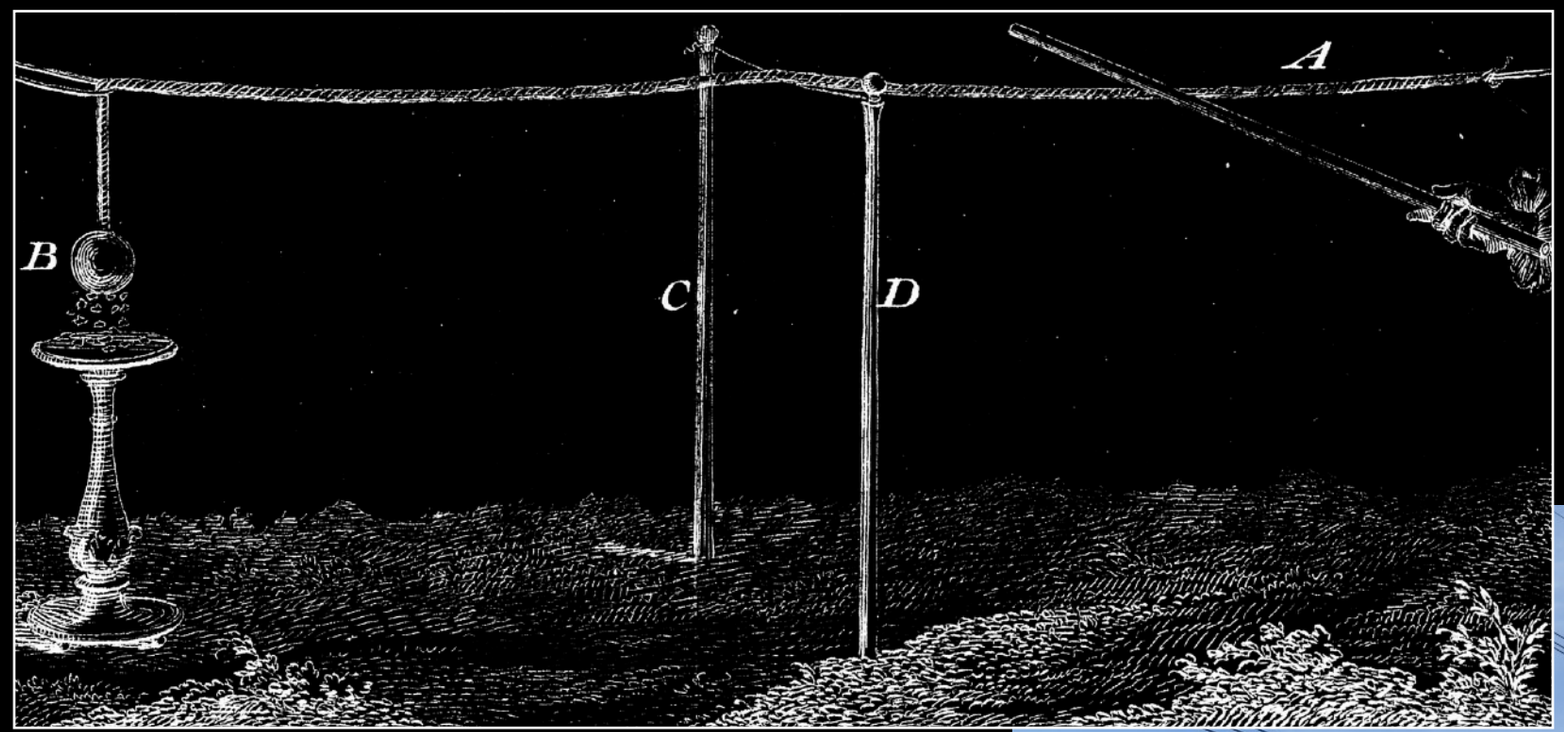
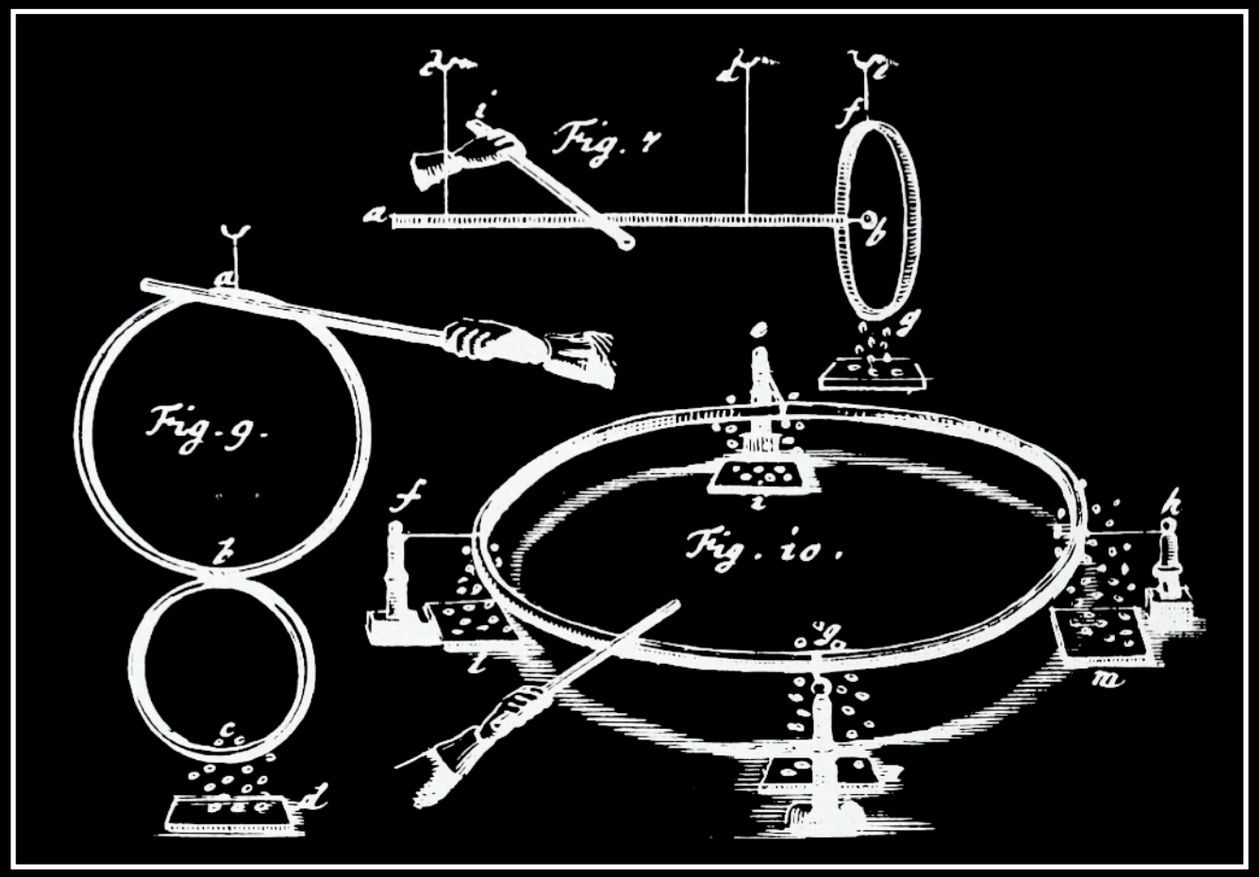
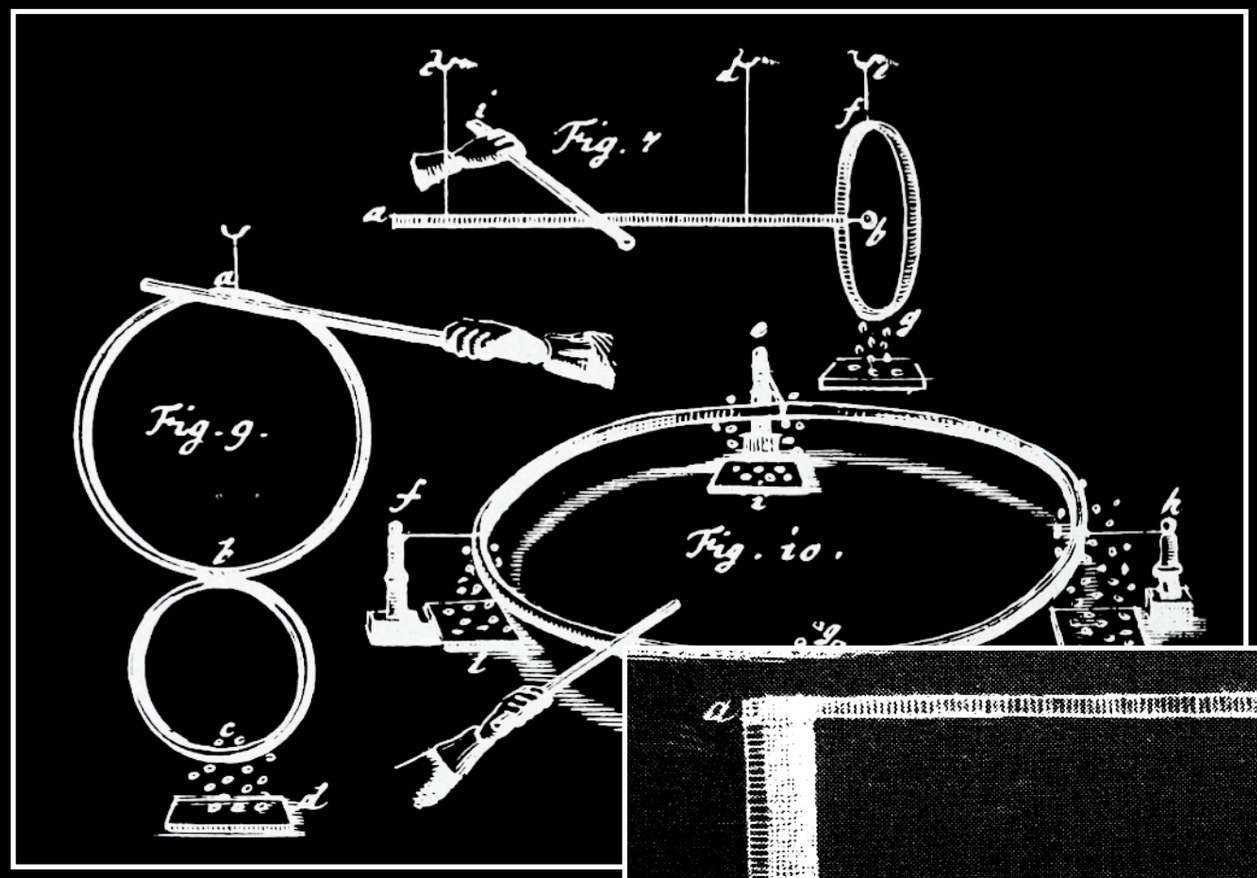


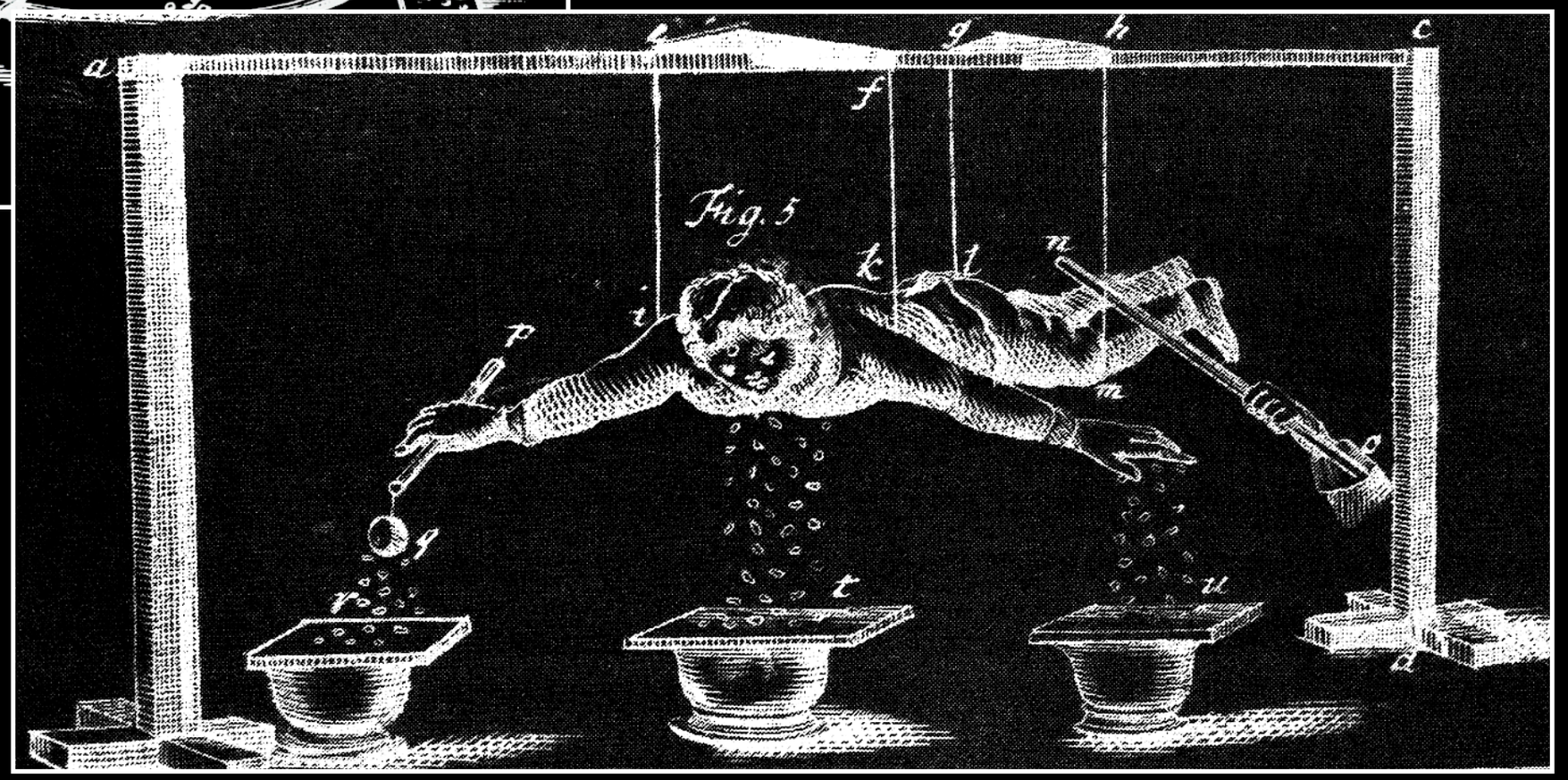
Further experiments

Further experiments



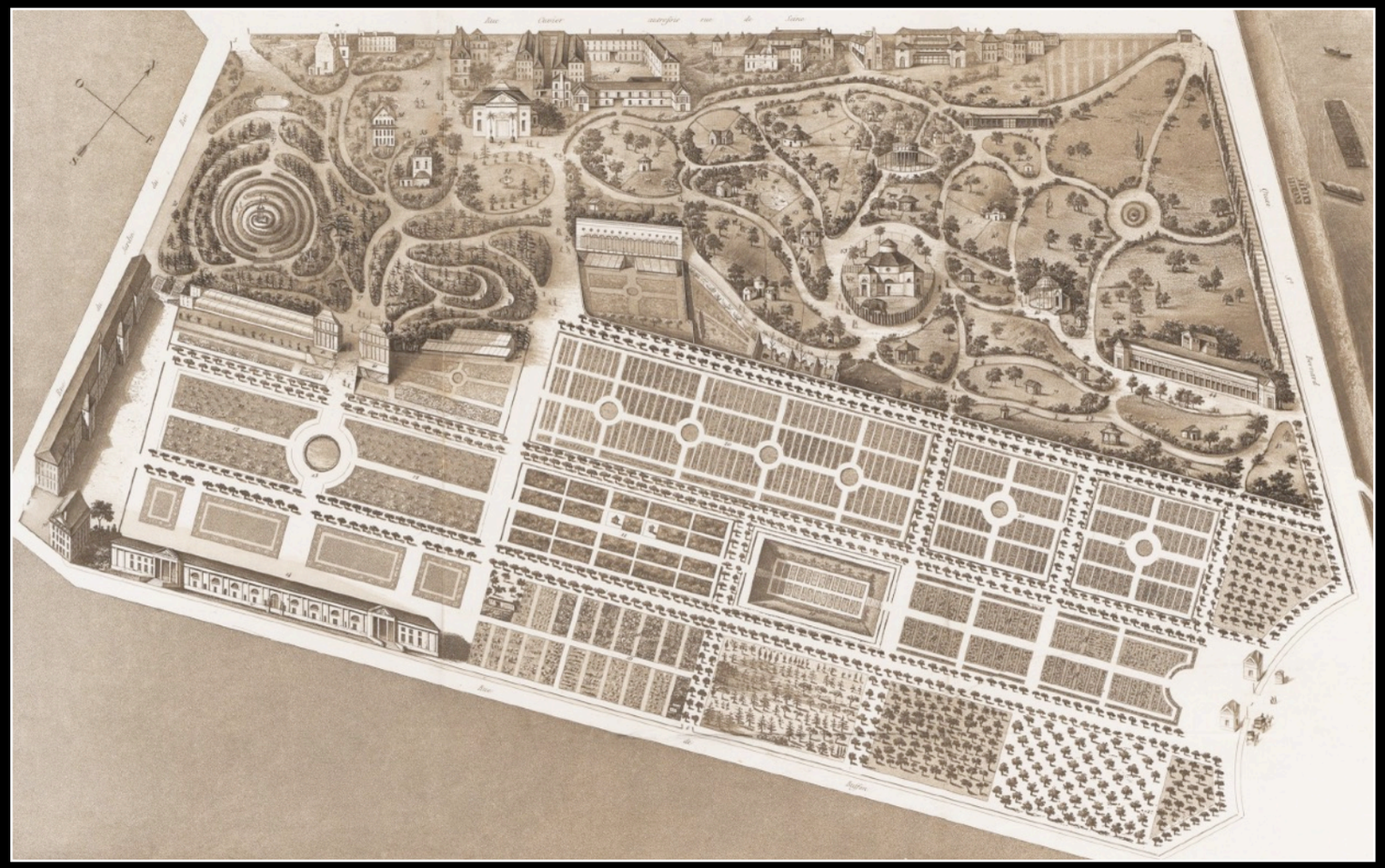
Further experiments





Charles du Fay

Lieutenant, gardener, academician



“Jardin du Roi”

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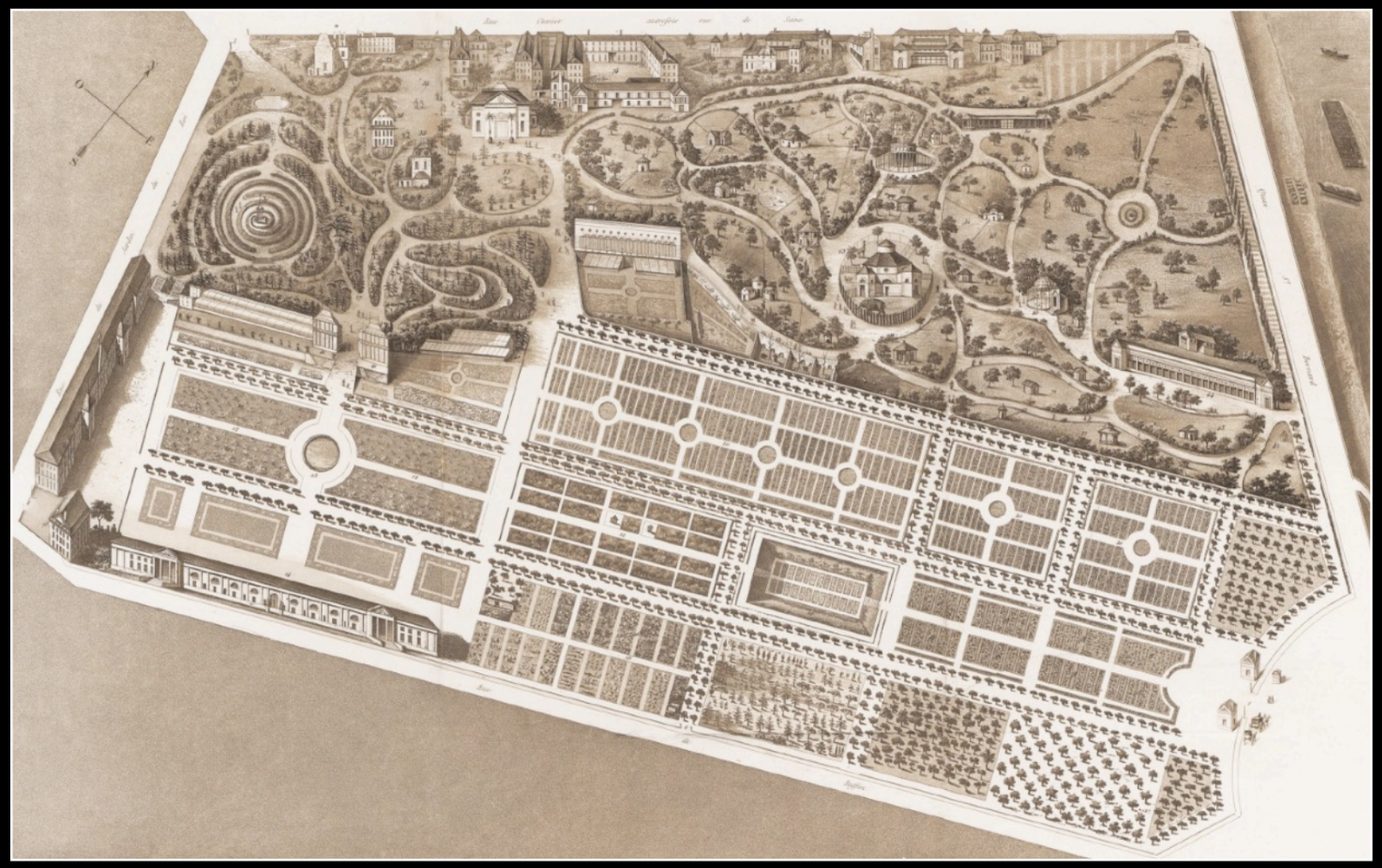


“Jardin du Roi”

V. *A Letter from Monſ.* Du Fay, *F. R. S. and of the Royal Academy of Sciences at* Paris, *to his Grace* CHARLES *Duke of* Richmond *and* Lenox, *concerning* Electricity. *Tranſlated from the* French *by* T. S. *M D.*

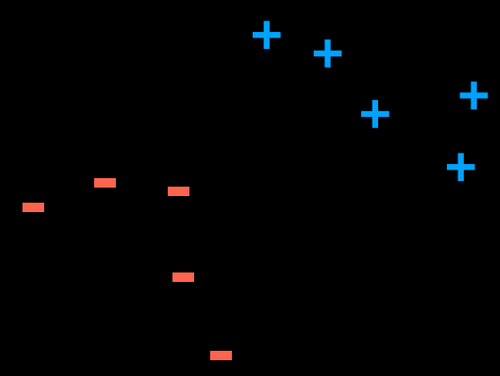
Paris, December 27, 1733.

My LORD,

I Flatter my ſelf your Grace will not be diſpleaſed with an Account of ſome extraordinary Diſcoveries I have made in the *Electricity* of Bodies, nor refuſe the Favour I have to aſk, that it may be communicated to the *Royal Society*. I owe this Homage to that Illuſtrious Body, not only as a Member thereof, but in this reſpect as a Debtor to their Works; for the Writings of Mr. *Gray*, and the late Mr. *Hauksbee*, both of that *Society*, firſt put me upon the Subject, and furniſh'd me with the Hints that led me to the following Diſcoveries.

A rigorous experimental programme

“I discovered a very simple principle, which accounts for a great part of the irregularities, and if I may use the term, of the caprices that seem to accompany most of the experiments on electricity.”



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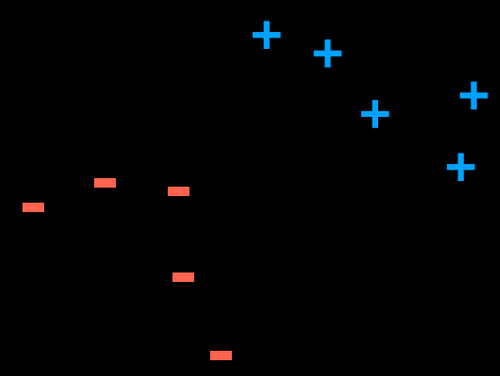
“I discovered a very simple principle, which accounts for a great part of the irregularities, and if I may use the term, of the caprices that seem to accompany most of the experiments on electricity.”

“First, I have found that all bodies (metallick, soft or fluid ones excepted) may be made Electrick, by first heating them more or less, and then rubbing them on any sort of cloth.”



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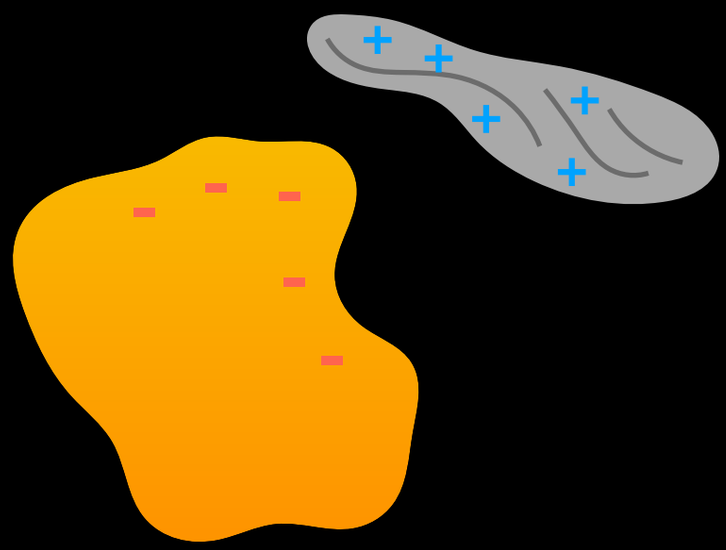

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“Second, I have found upon trial, that all bodies (being fix’d to a stand, and that set on a plate of glass or wax) may be made electrical, without exception, whether solid or fluid, by making contact with the excited glass tube.”

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"DuFay's rule"

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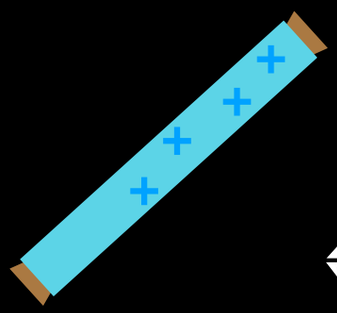

“Vitreous”

“The first is that of glass, precious stones, wool, and many other bodies.”

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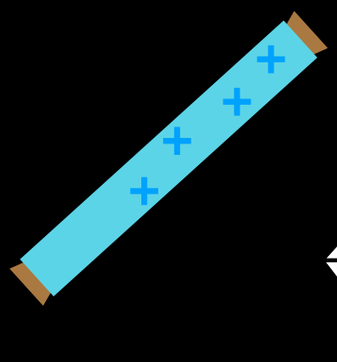
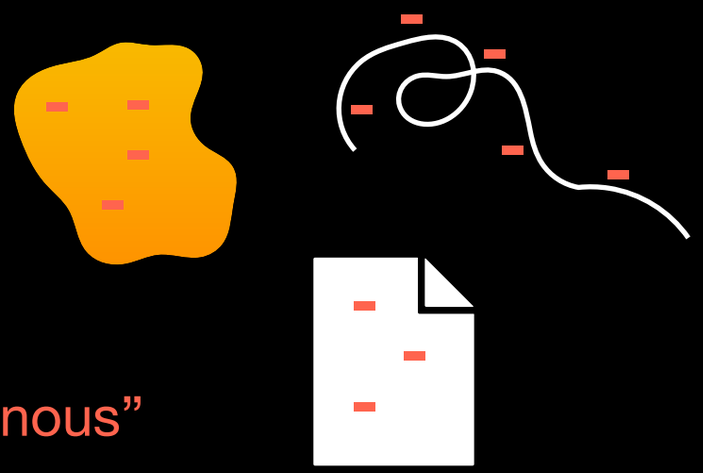


“Vitreous”

“The first is that of glass, precious stones, wool, and many other bodies.”

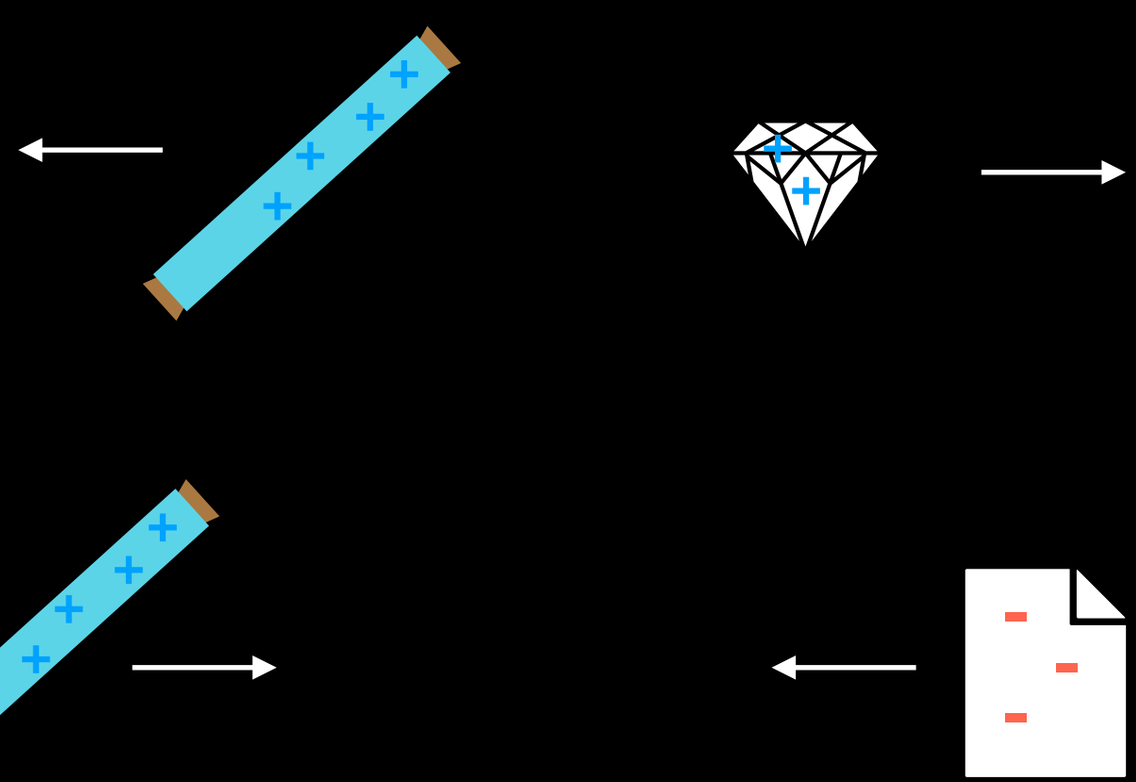
“The second is that of amber, silk, thread, paper, and a vast number of other substances.”



“Resinous”

Two kinds of electricity?!

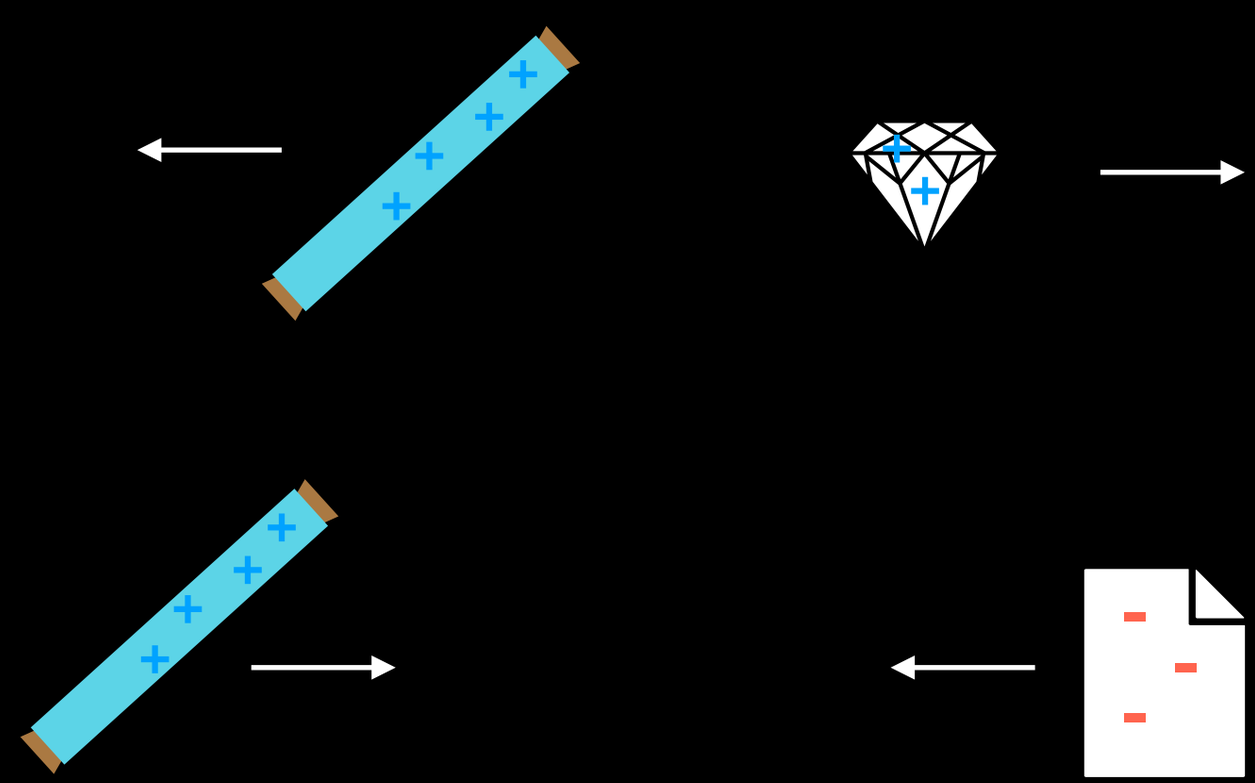
“[…] and on the contrary, attracts all those of the resinous electricity.”



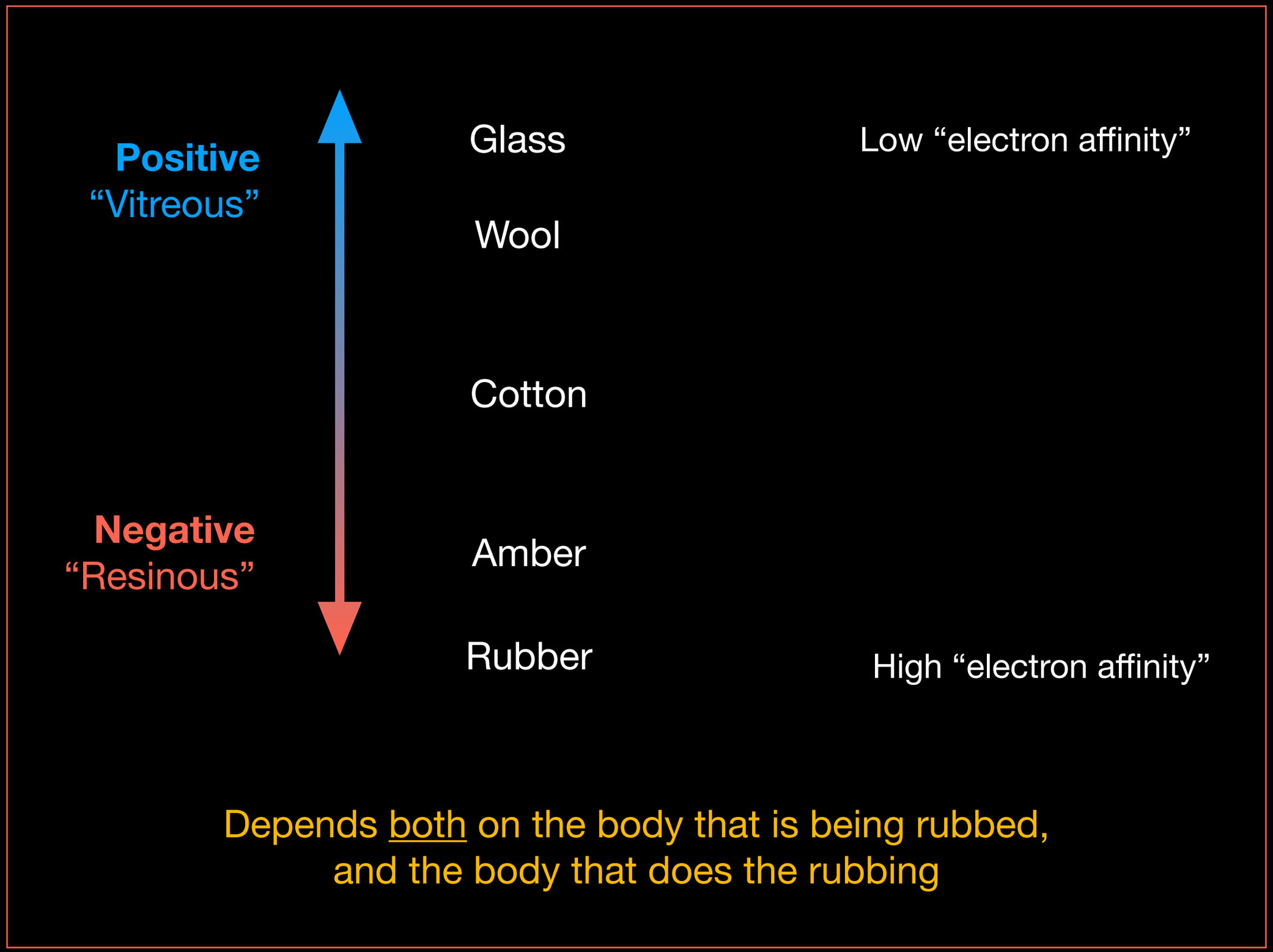
Two kinds of electricity?!

“The characteristick of these two electricities is, that a body of the vitreous electricity, for example, repels all such as are of the same electricity […]”

“[…] and on the contrary, attracts all those of the resinous electricity.”



Today: the tribo-electric series



Depends <u>both</u> on the body that is being rubbed,
and the body that does the rubbing

Electricity as entertainment *(ca. 1740)*

Electricity as entertainment *(ca. 1740)*

[source]

“Beatification”

Electricity as entertainment *(ca. 1740)*

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“Beatification”

“Electric kiss”

Electricity as entertainment *(ca. 1740)*

"Beat

Gray's "boy" reaches Versailles

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Electricity as entertainment *(ca. 1740)*

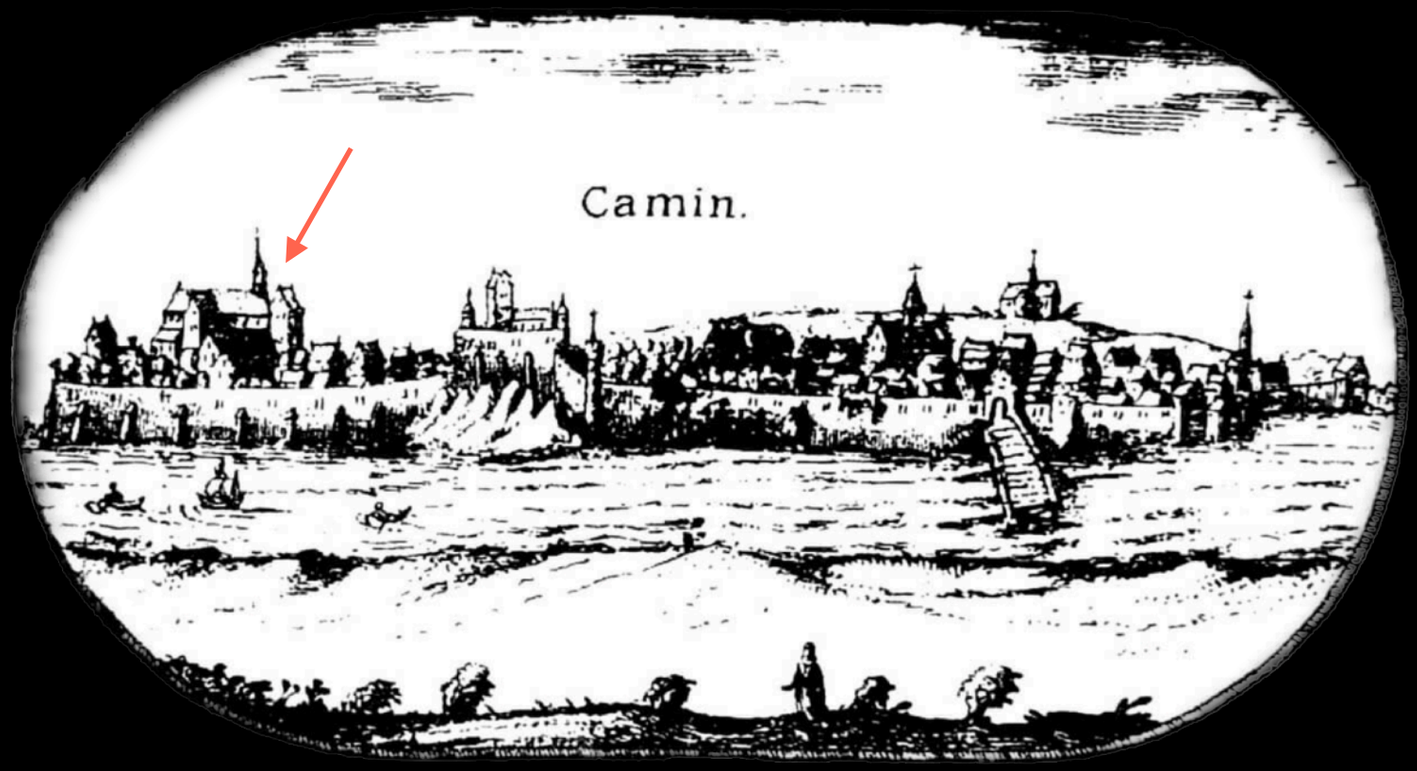
Institute and Museum of the History of Science, Florence [link]

"Drawing fire from water"

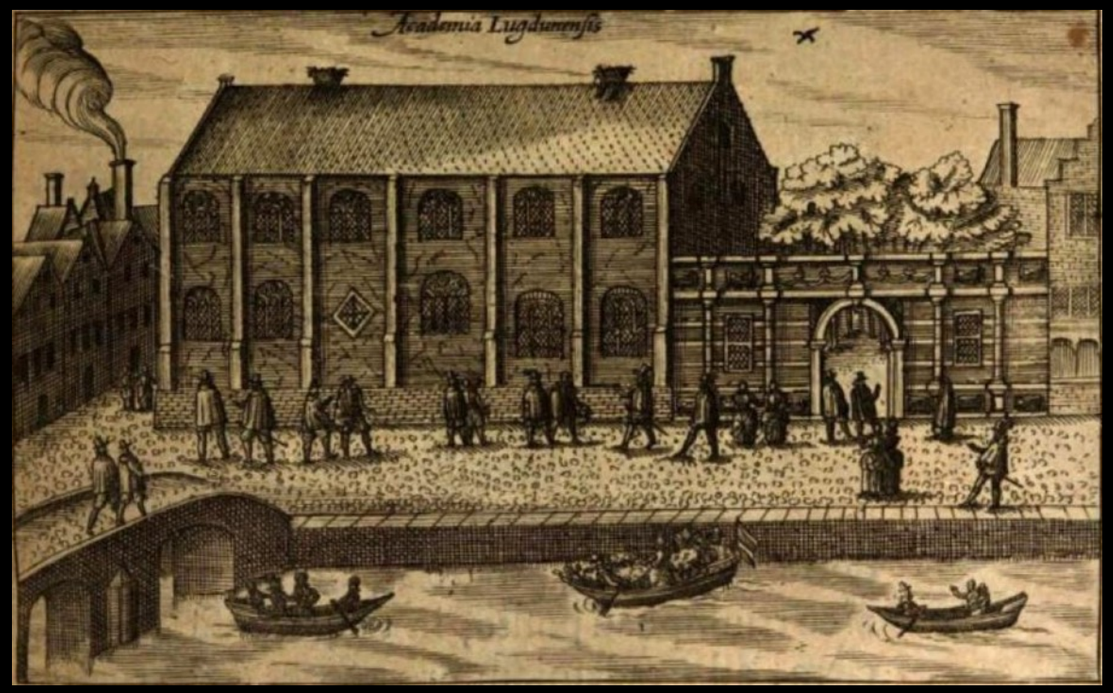
Gray's "boy" reaches Versailles

Electricity in Prussia: Ewald von Kleist

Cleric, judge, dabbler

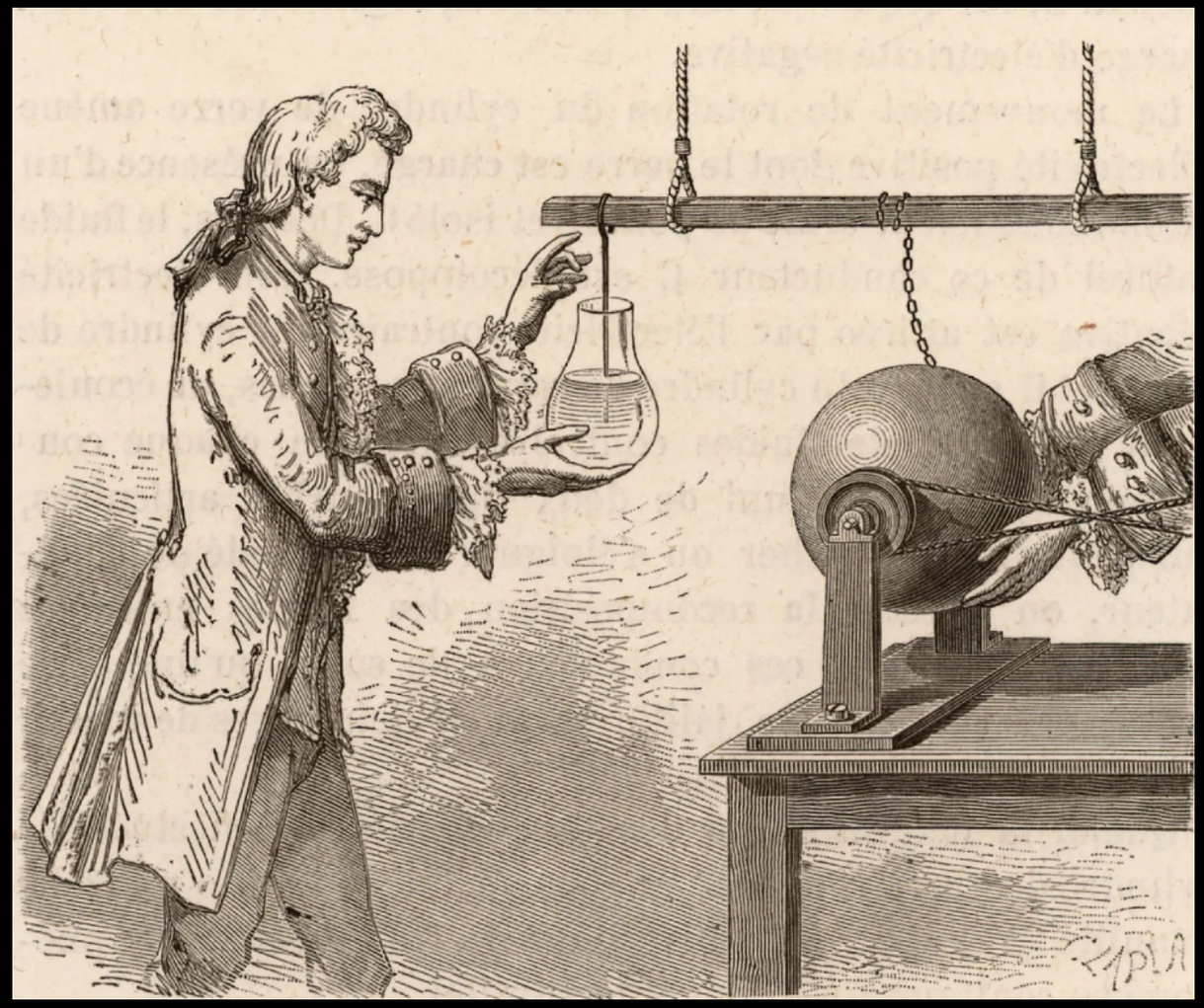


Kamień Pomorski



University of Leyden

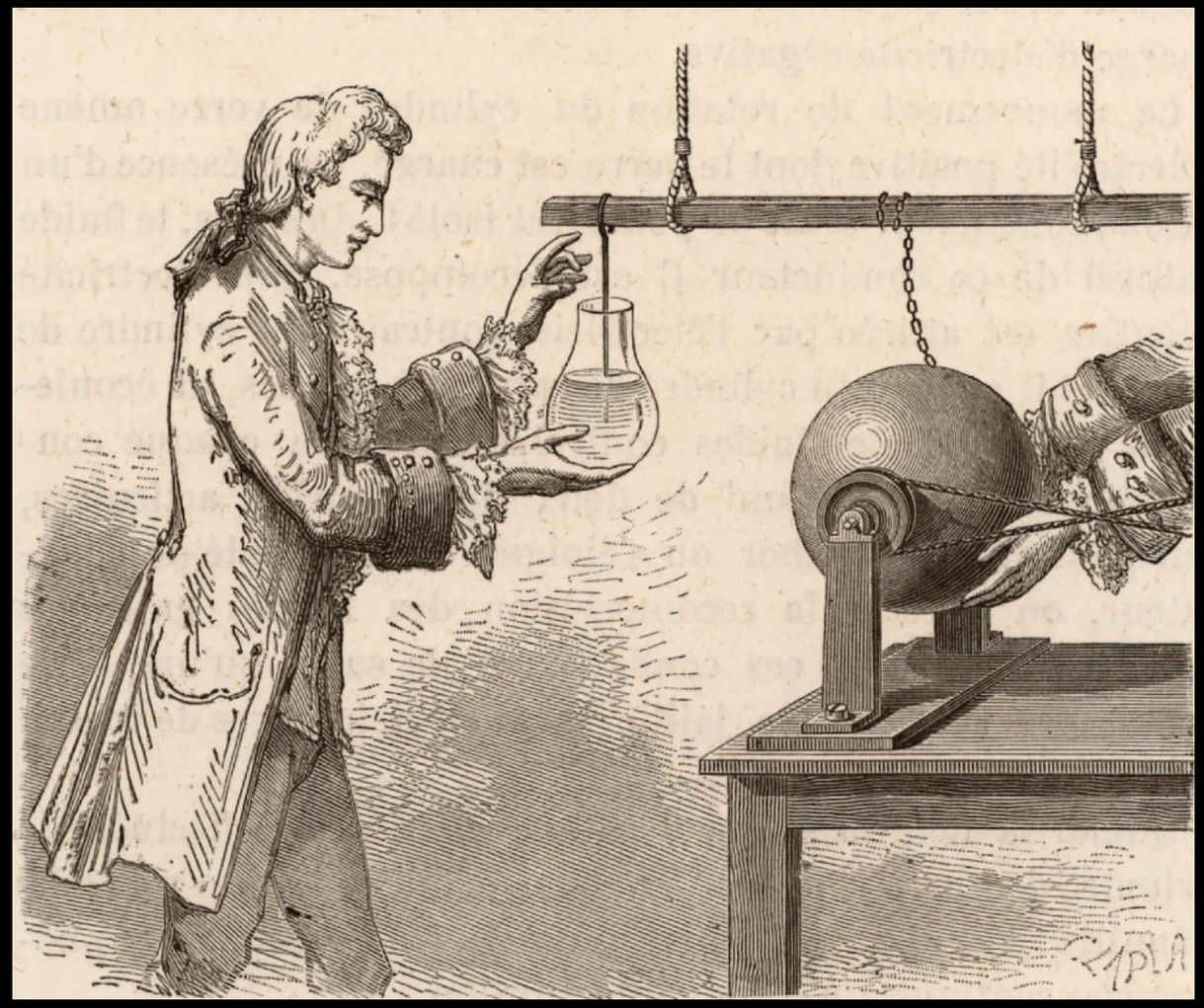
A portable “sparking machine”



October 11, 1745:

“If a nail, a strong wire, etc., is introduced into a narrow-necked little medicine bottle and electrified, especially powerful effects follow.
Everything works better if a little mercury or alcohol is placed inside.”

A portable “sparking machine”



October 11, 1745:

“If I electrify the nail strongly, I can take it into another room and ignite spirit of wine or terpentine.”

Defying du Fay’s rule

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J. N. Lieberkühn from Berlin: *“novel and remarkable”*

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Du Fay’s rule: body placed
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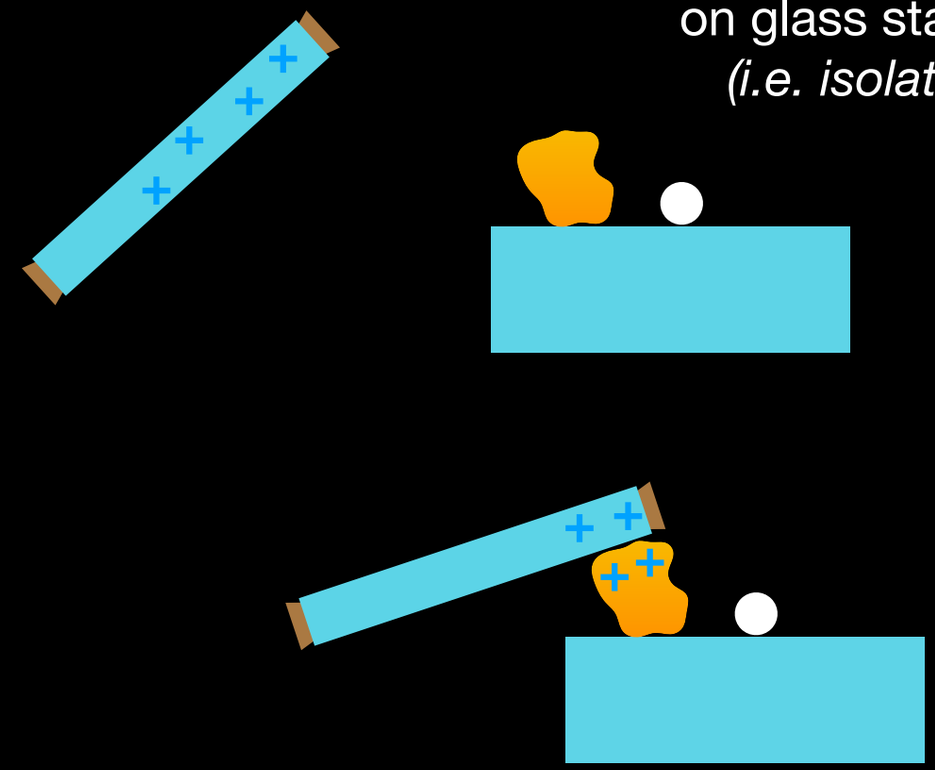

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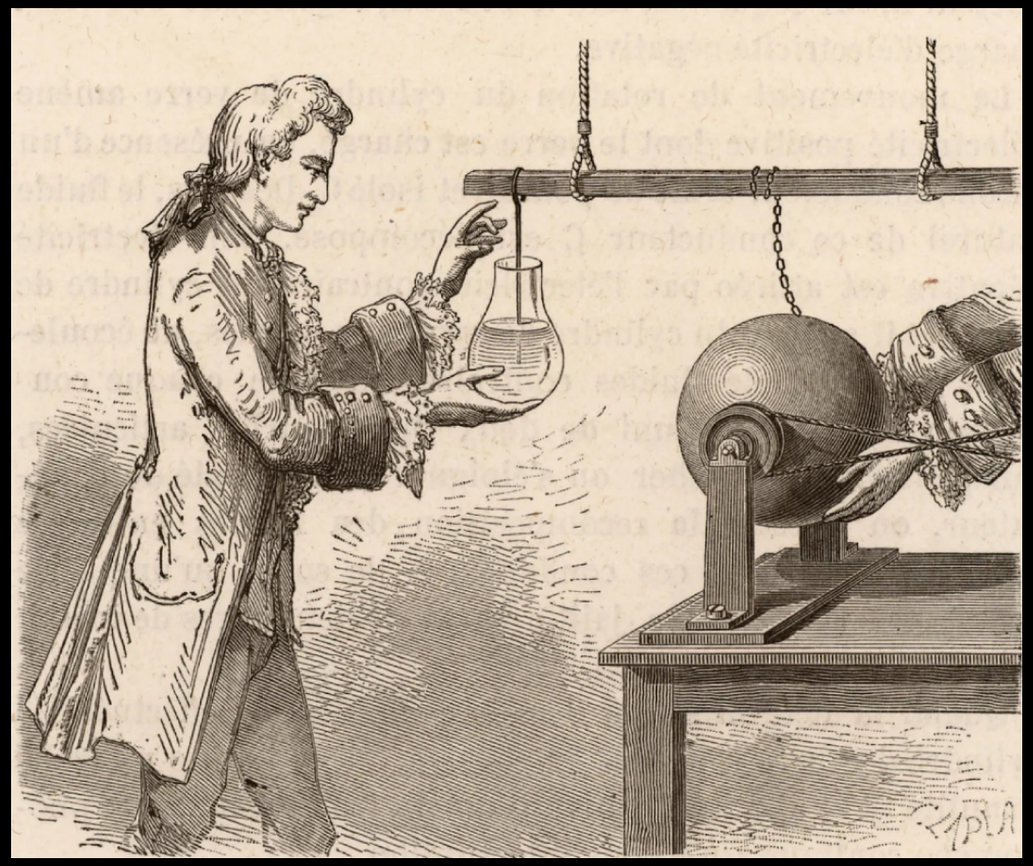

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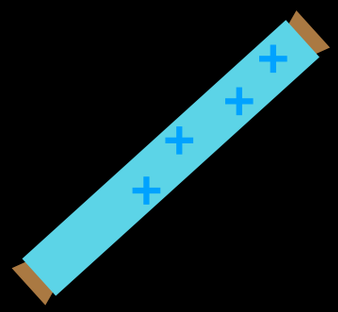

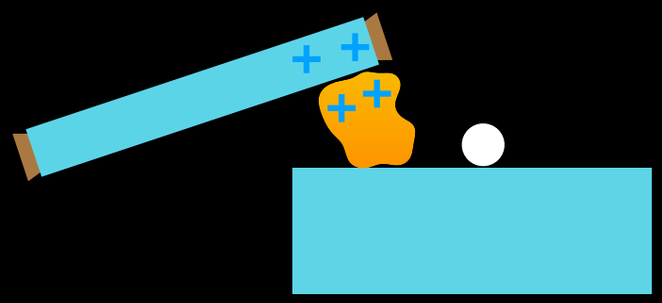

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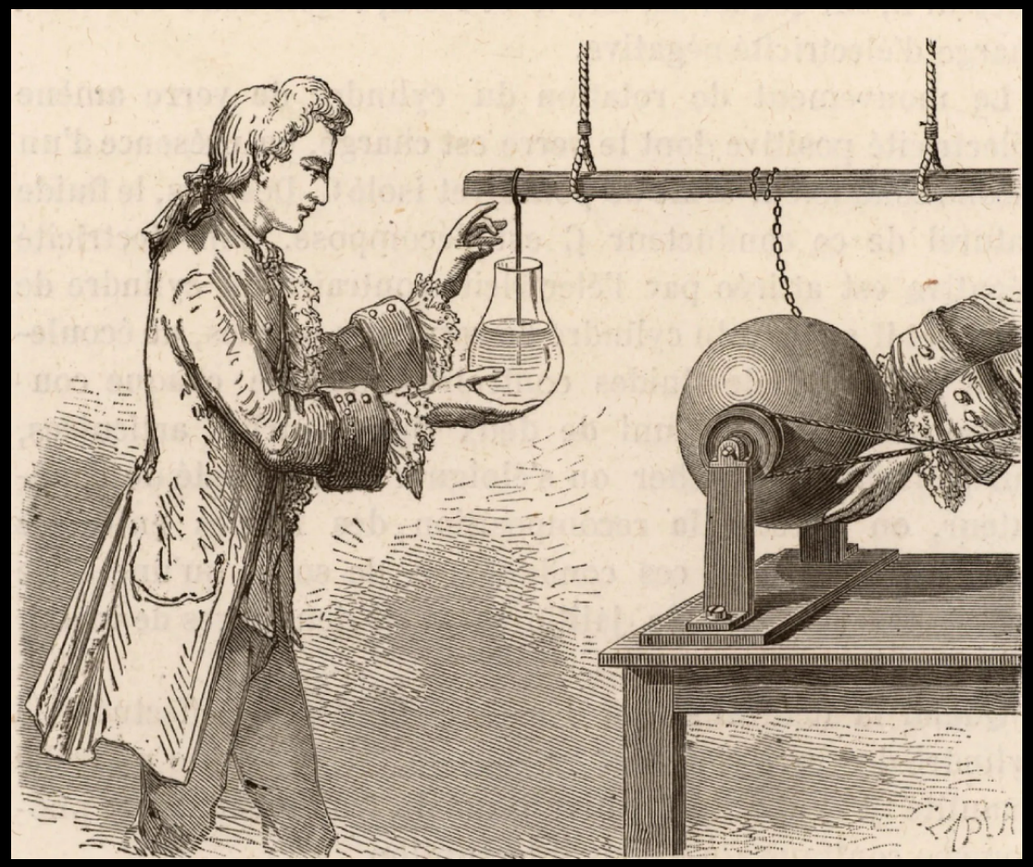

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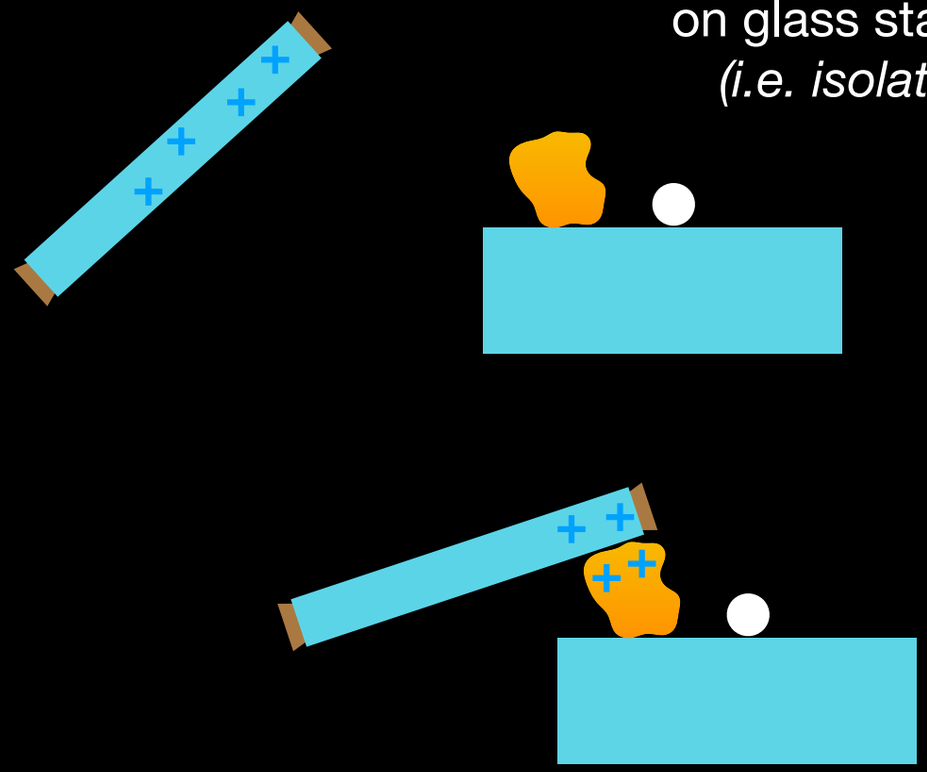

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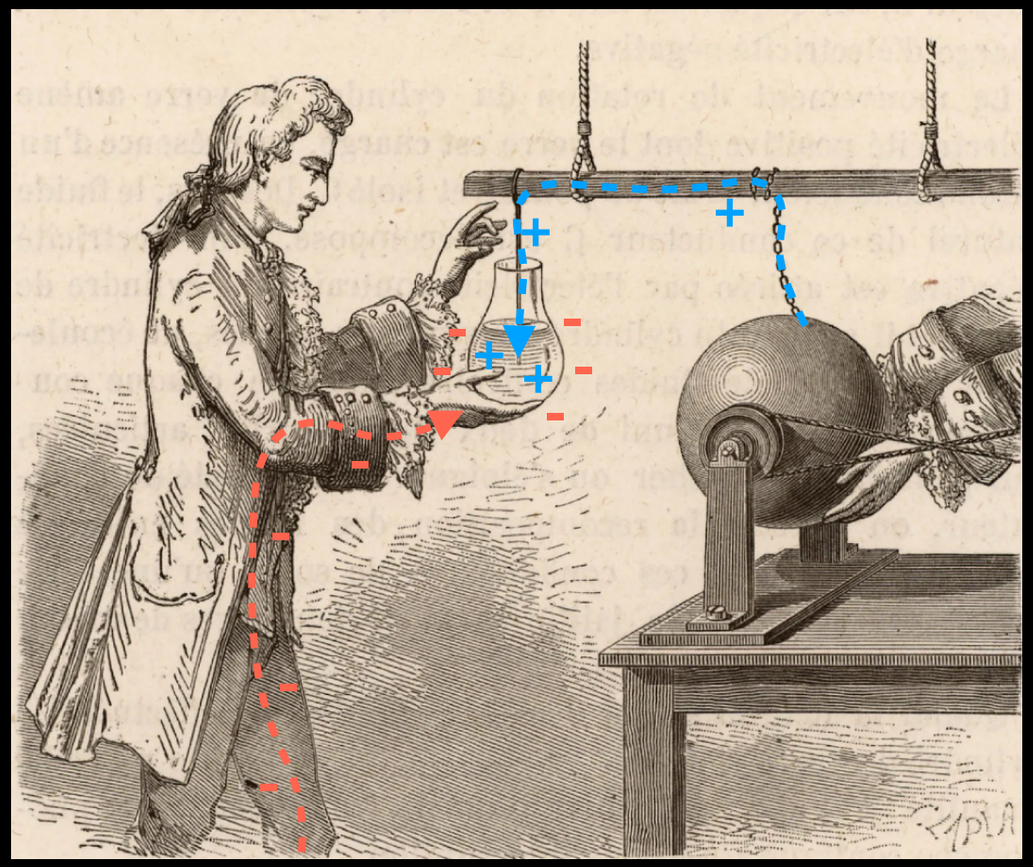

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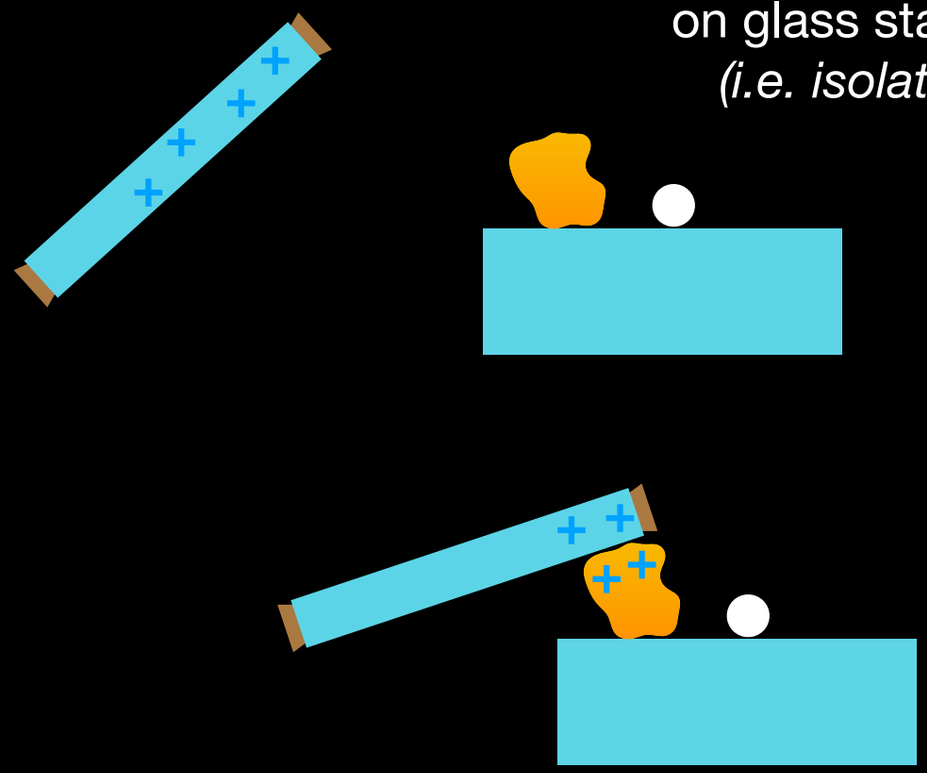

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The rediscovery at Leyden

Pieter van Musschenbroek:

“I would like to tell you about a new but terrible experiment, which I advise you never to try yourself, nor would I, who have experienced it and survived by the grace of god, do it again for all the kingdom of France.”

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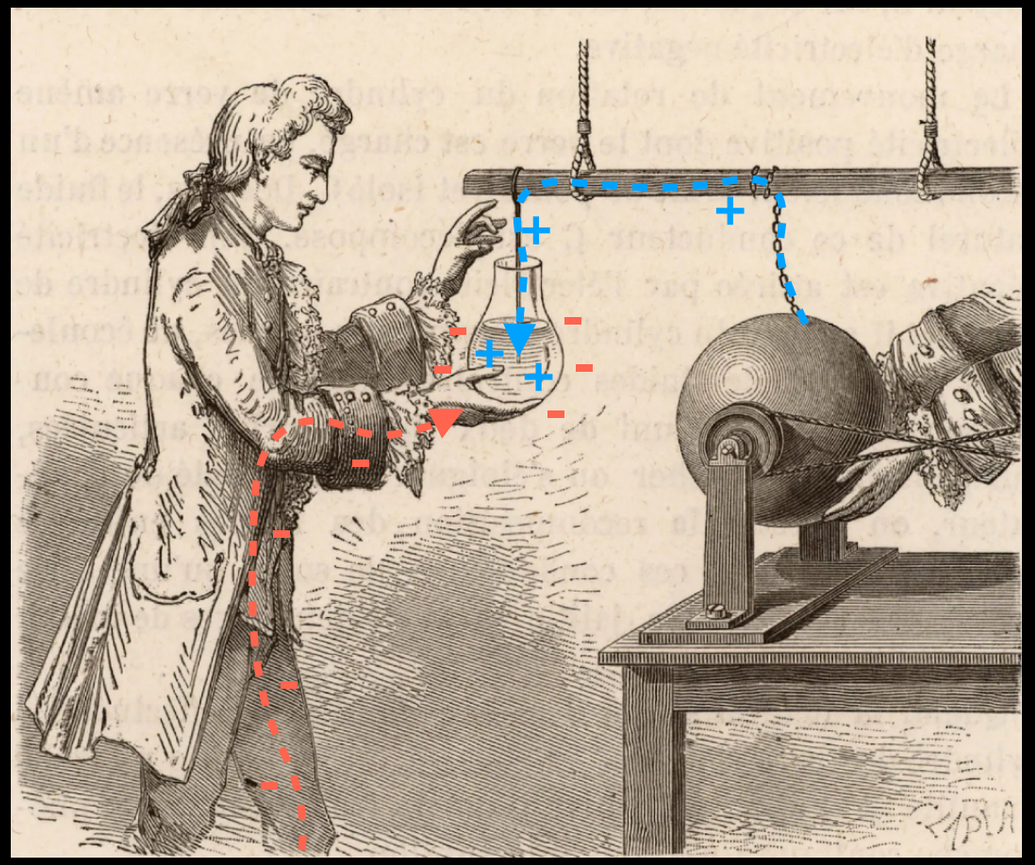

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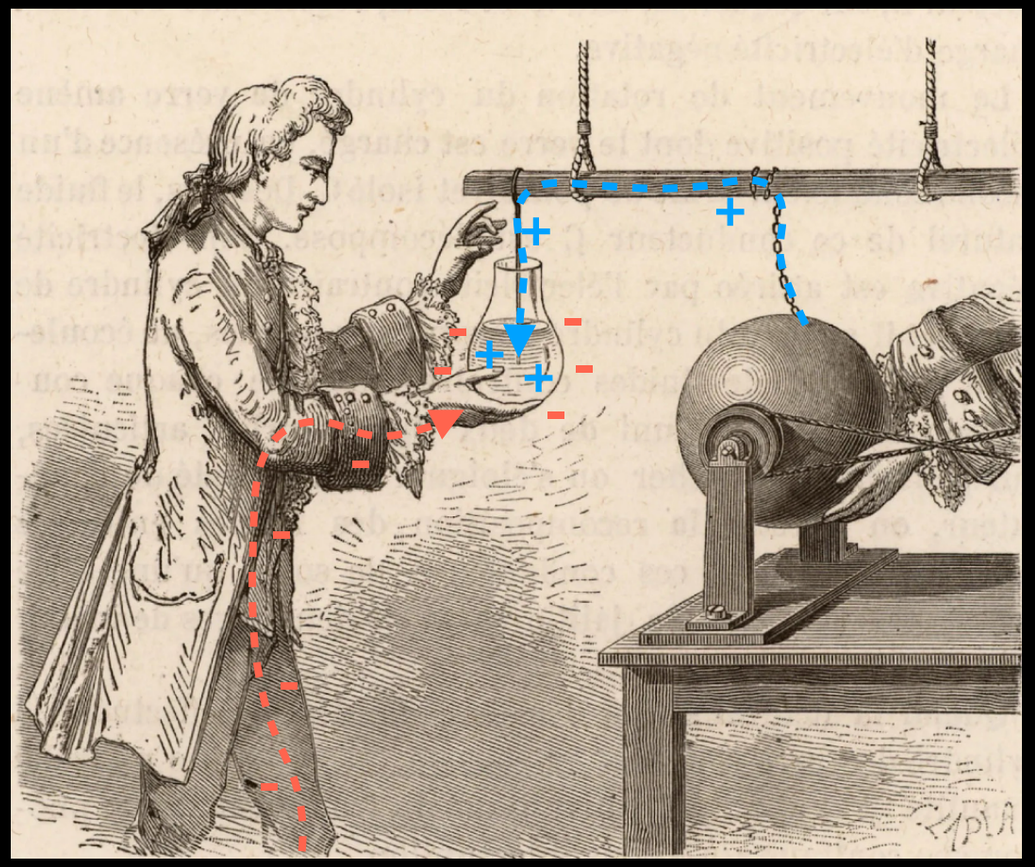
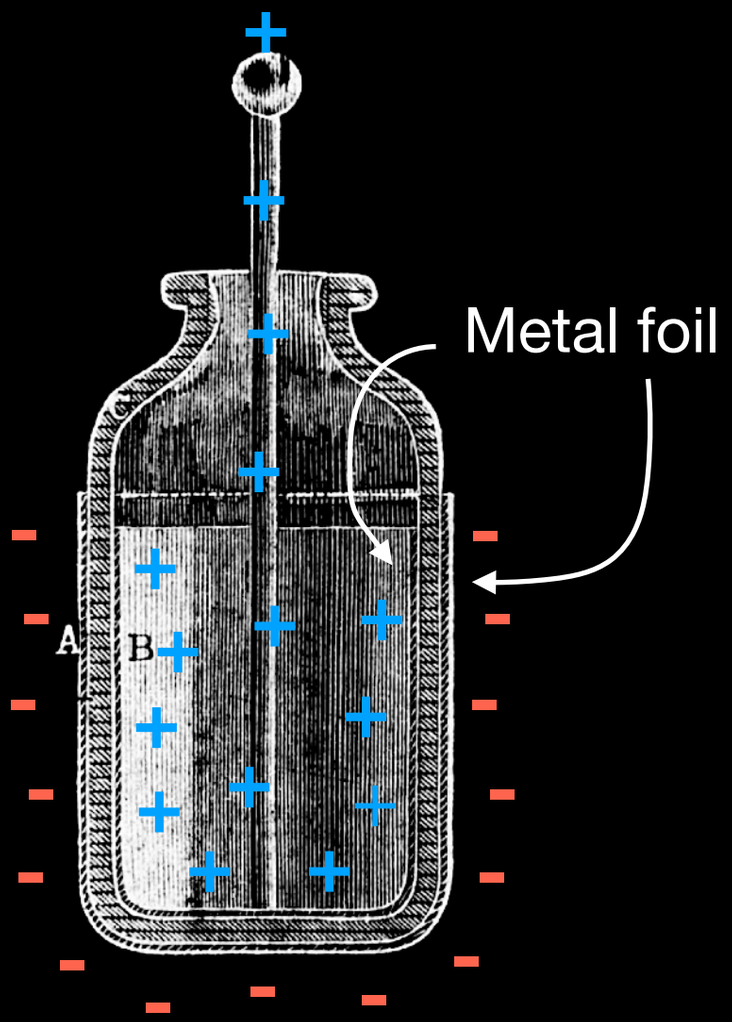


"No one ever thought that the Rule of du Fay must allow an exception in the case of glass."

Experiments with the “Leyden Jar”



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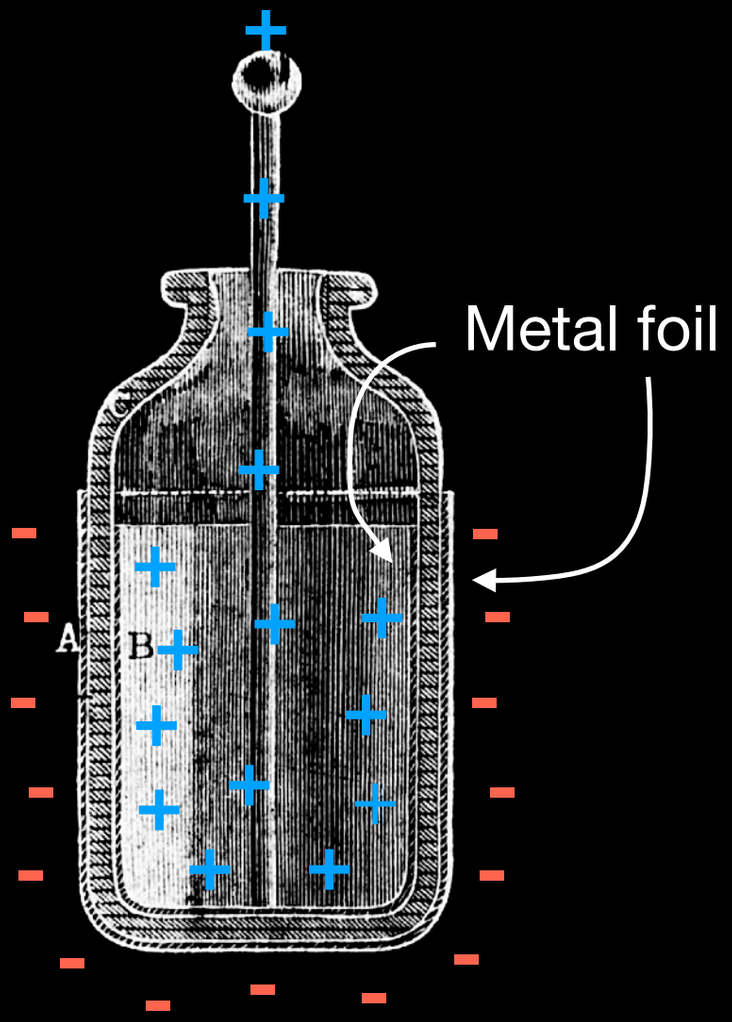

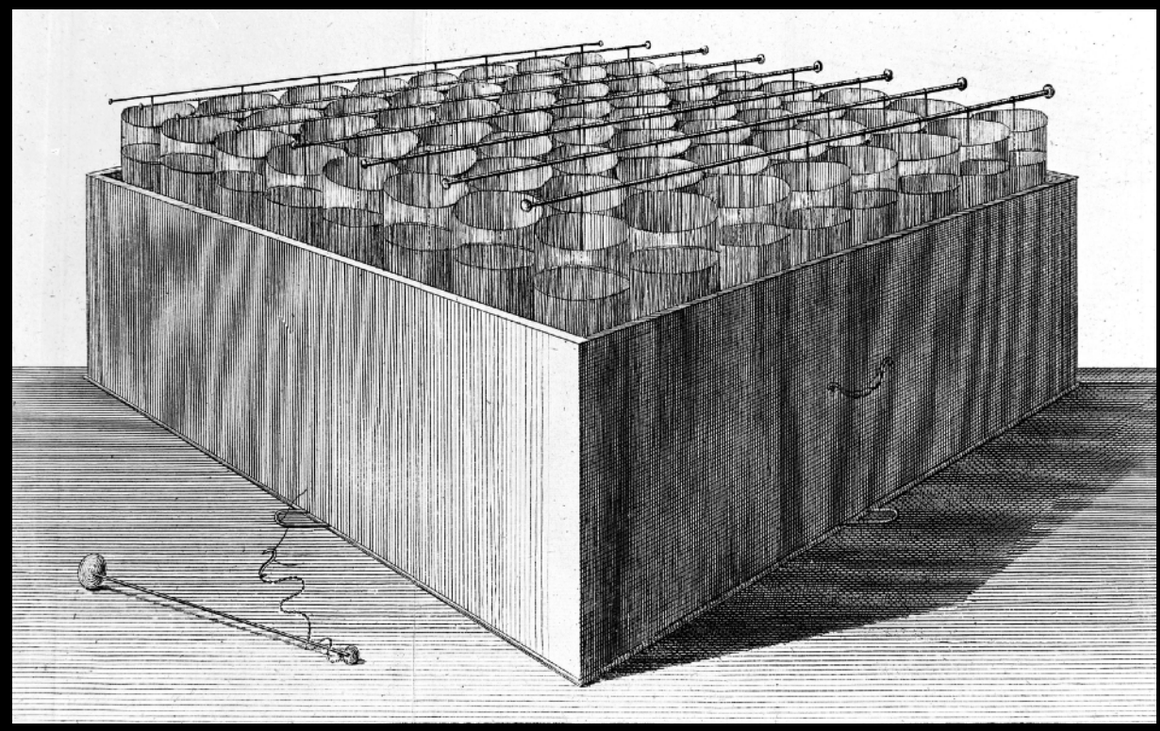

“Battery” of Leyden Jars

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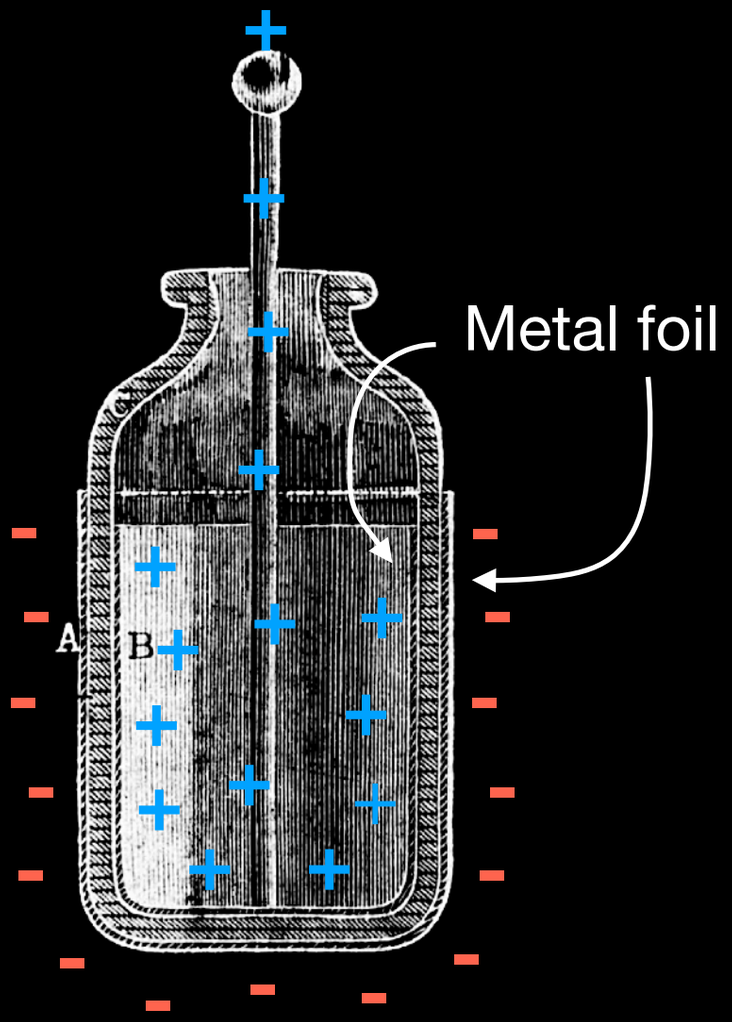

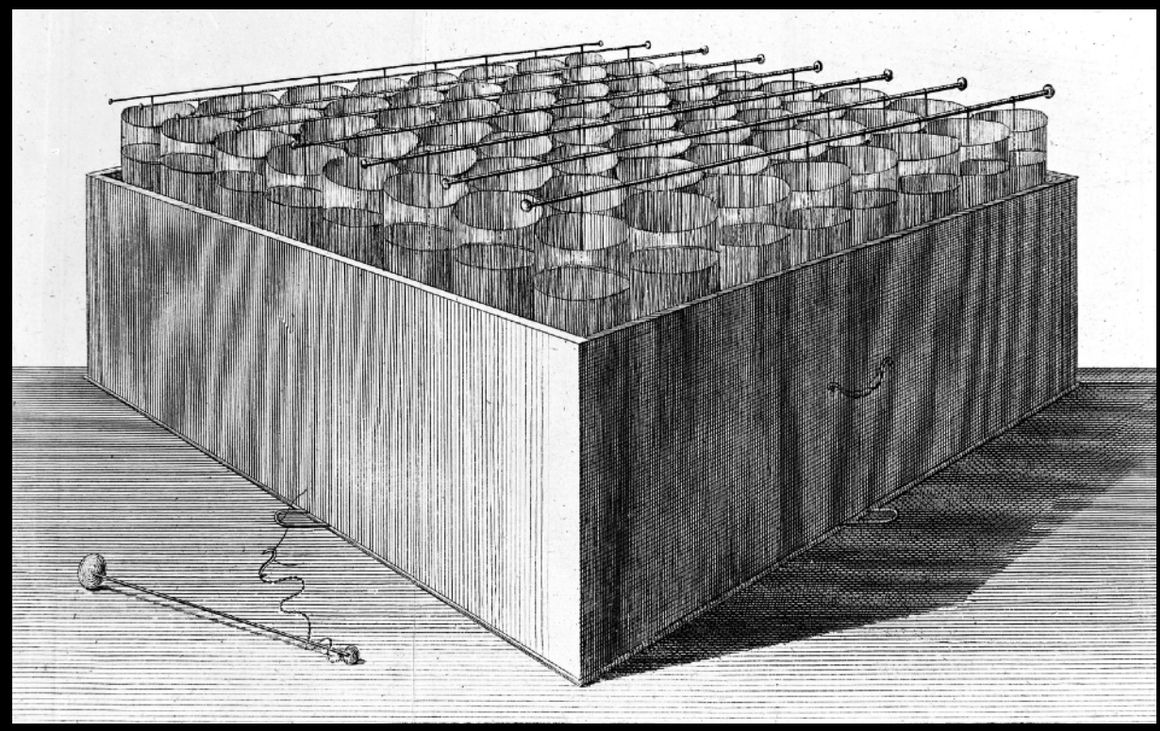

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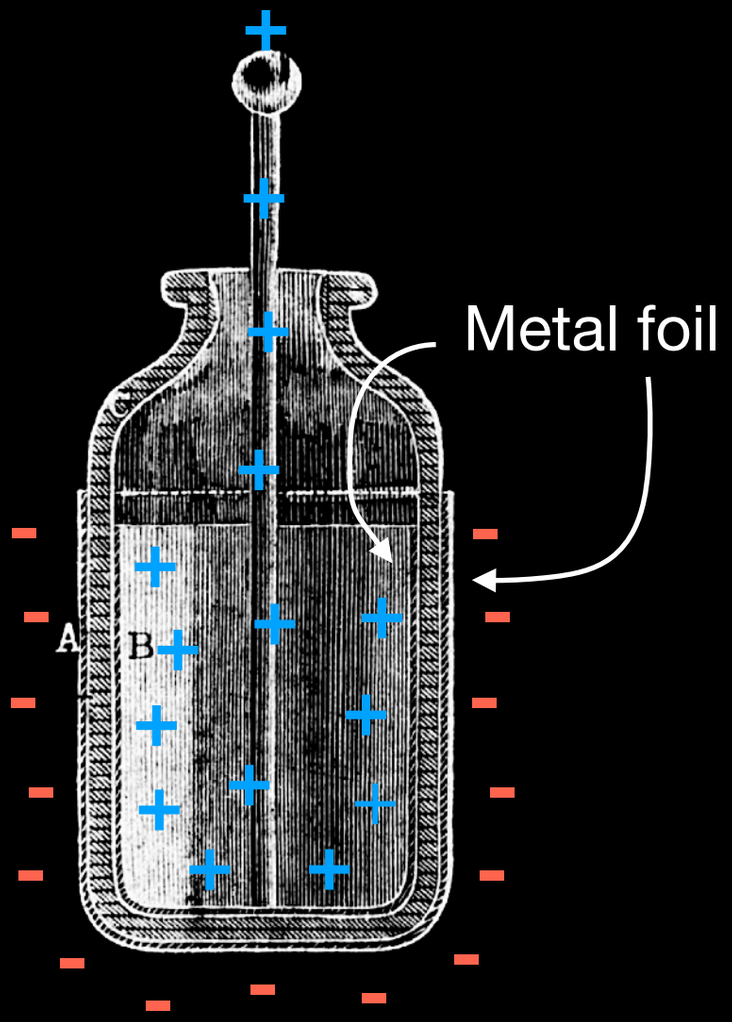

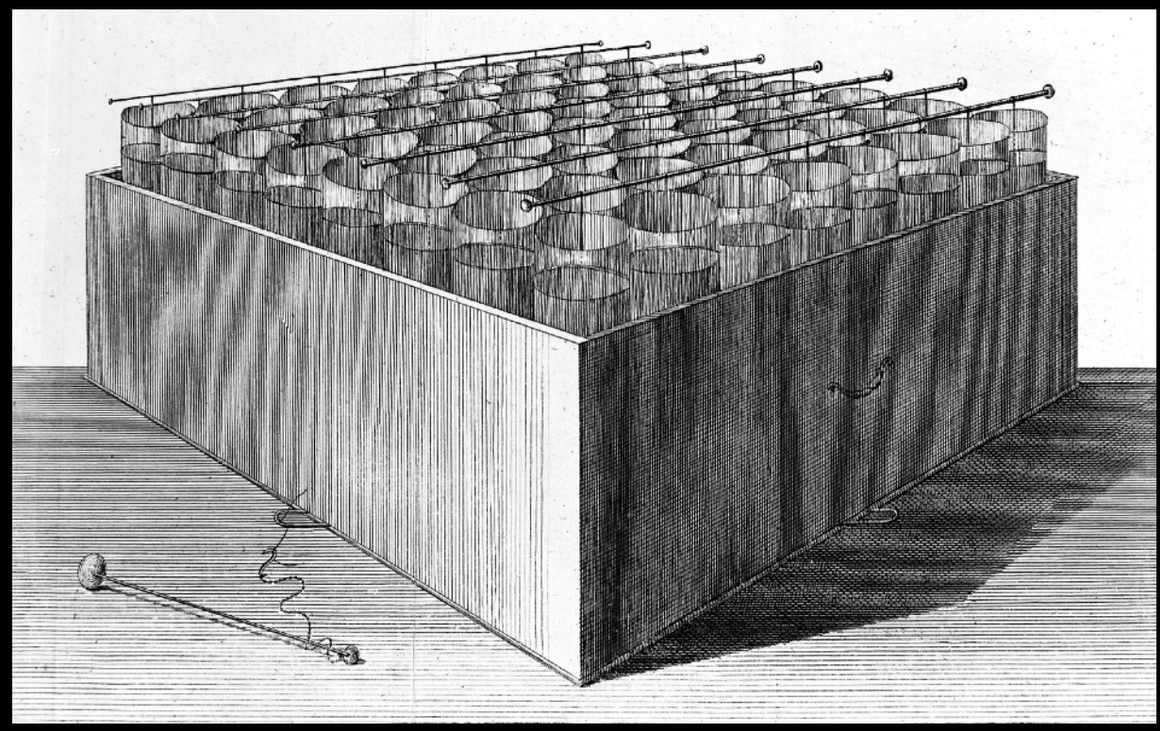

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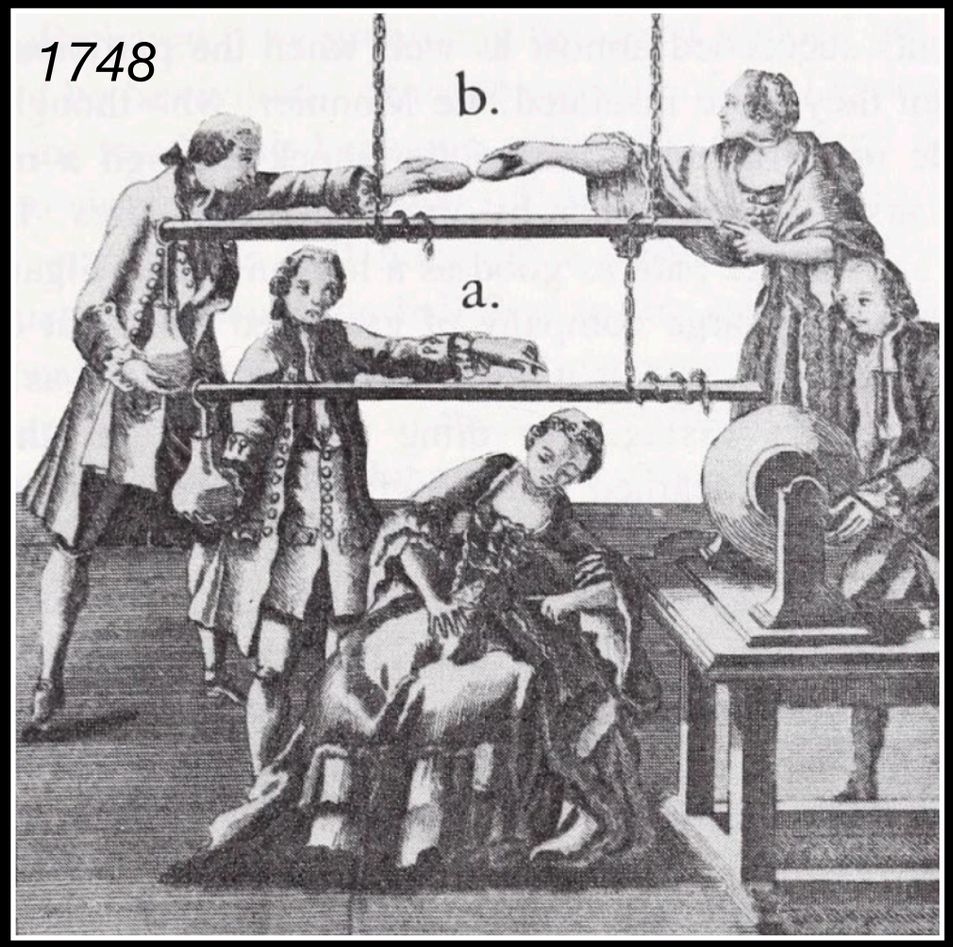
“The one who does the operation must be very aware, lest it happen to him, to mortify his own flesh instead of that of his hen.”

“Mass electrifications” à la Leyden



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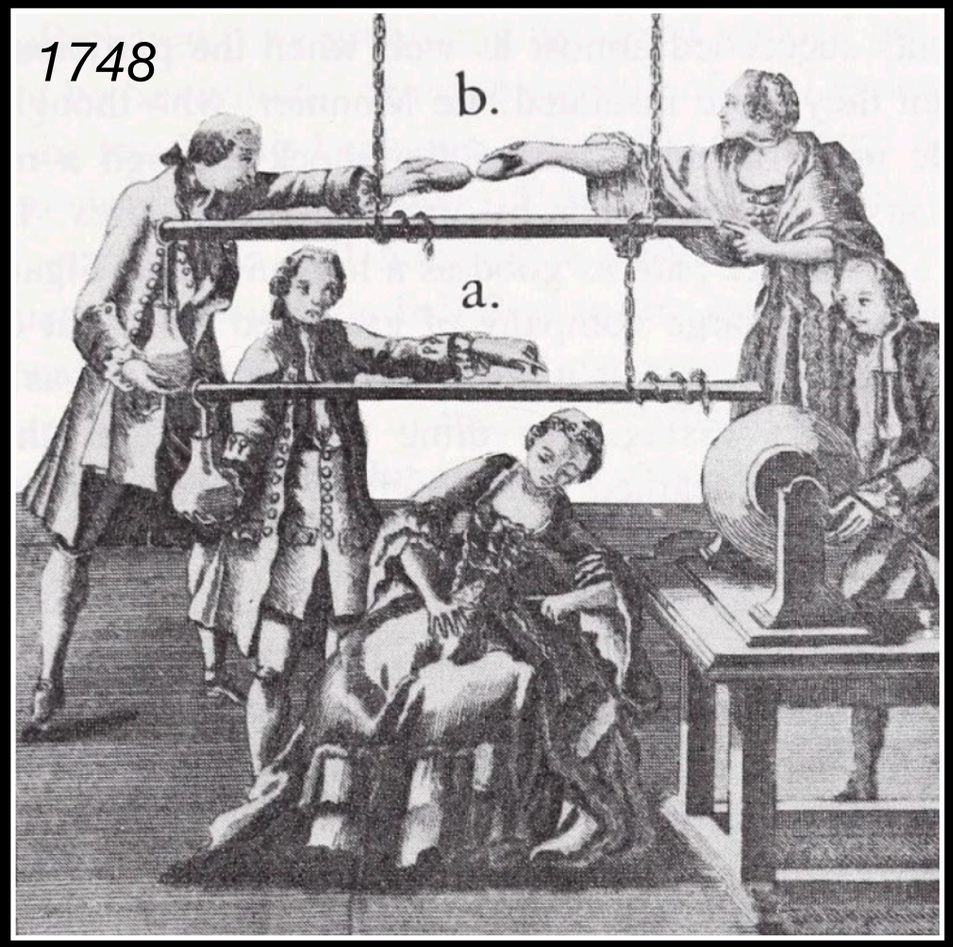

Discovery of the electrical “circuit”:

(a) receives a much stronger shock than **(b)**

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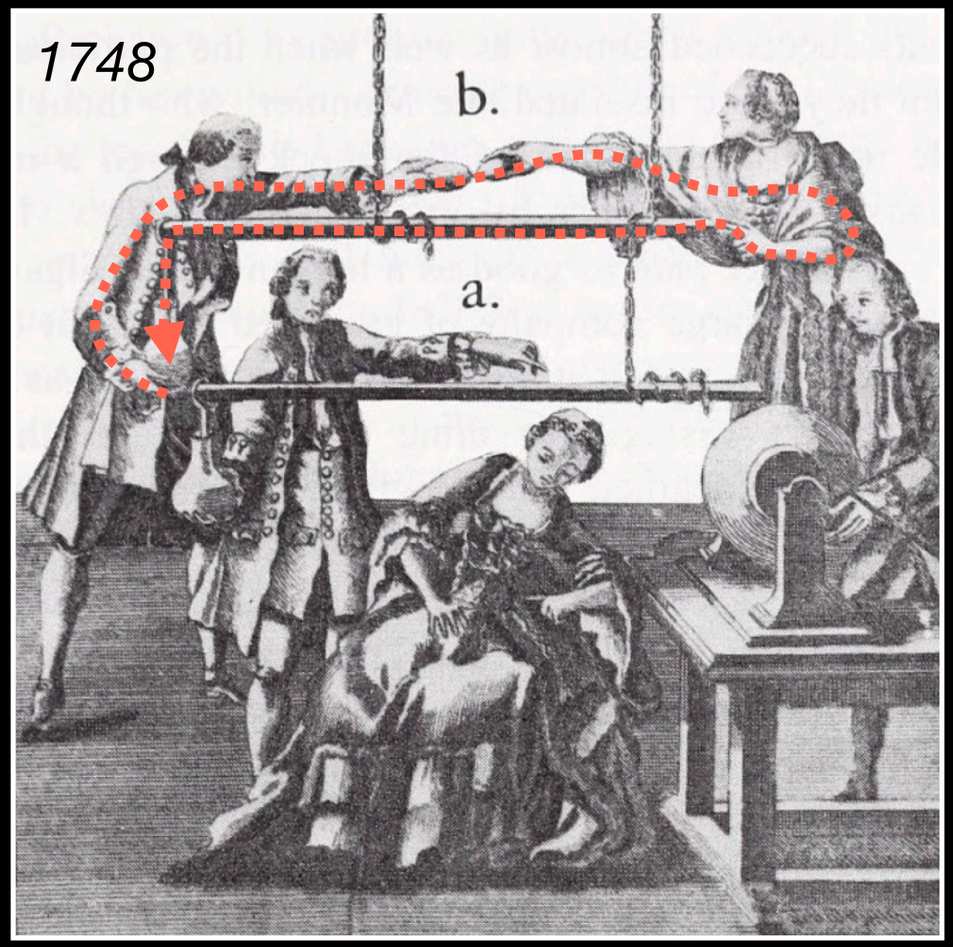

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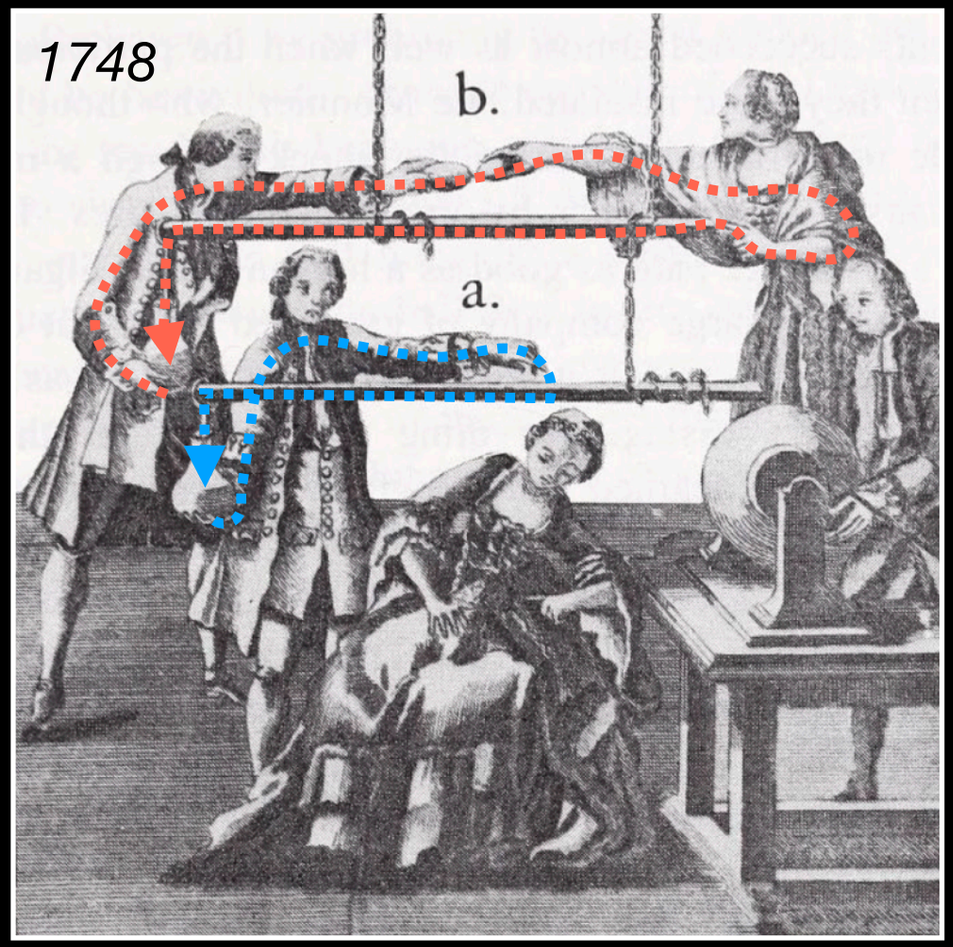

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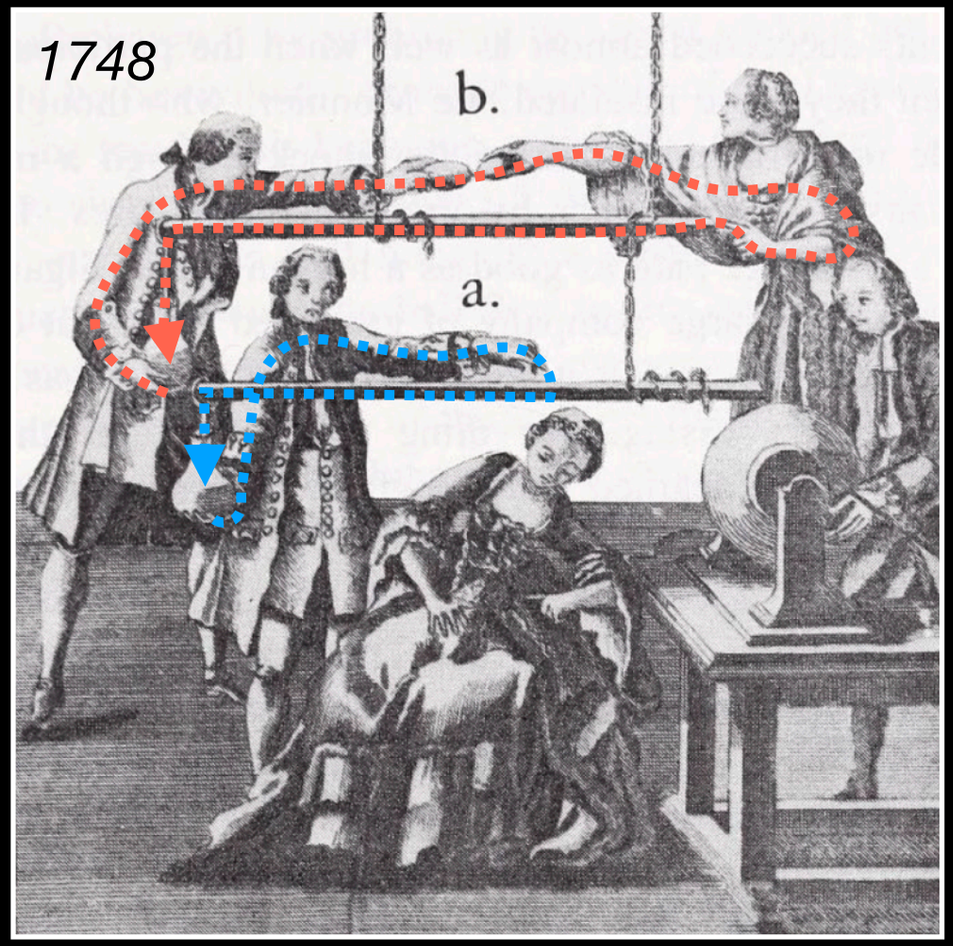

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Japanese
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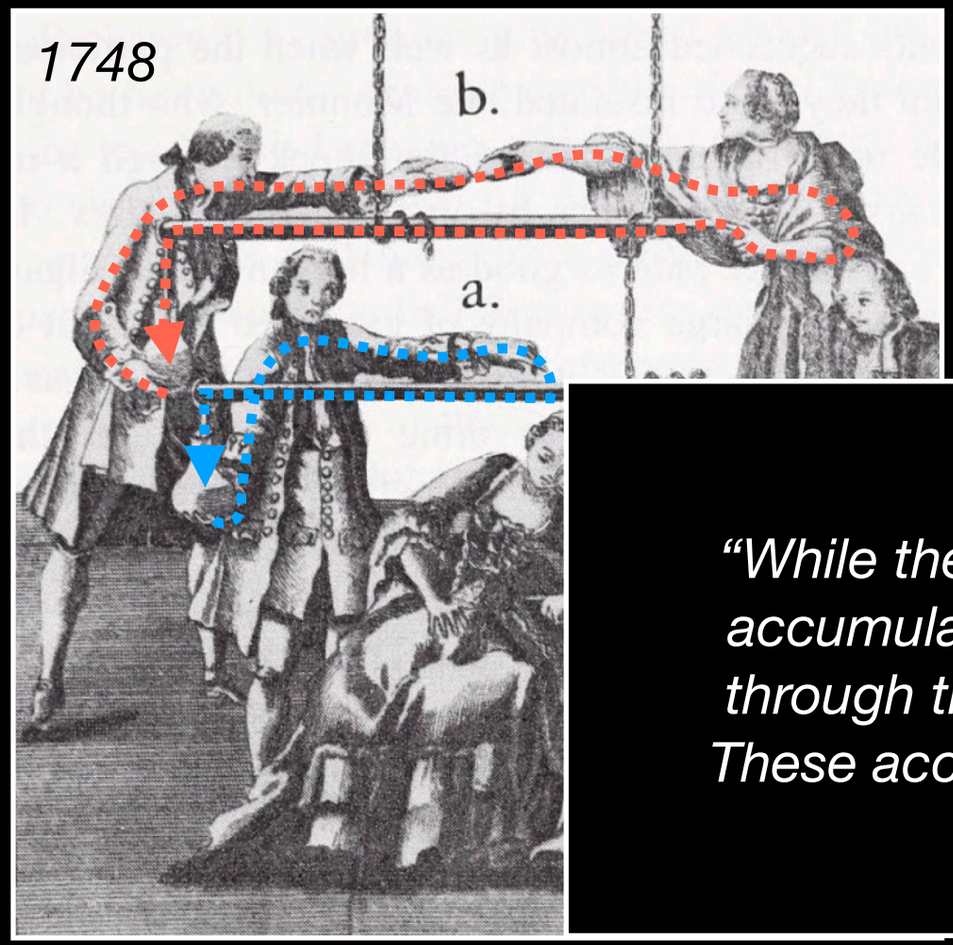

Discovery of the electrical “circuit”:

(a) receives a much stronger shock than **(b)**

Utter confusion:

“While the bottle charges, electrical aether accumulates in the water and, by seeping through the glass, in the bottom of the jar. These accumulations set up local, peaceful double fluxes.”

Japanese
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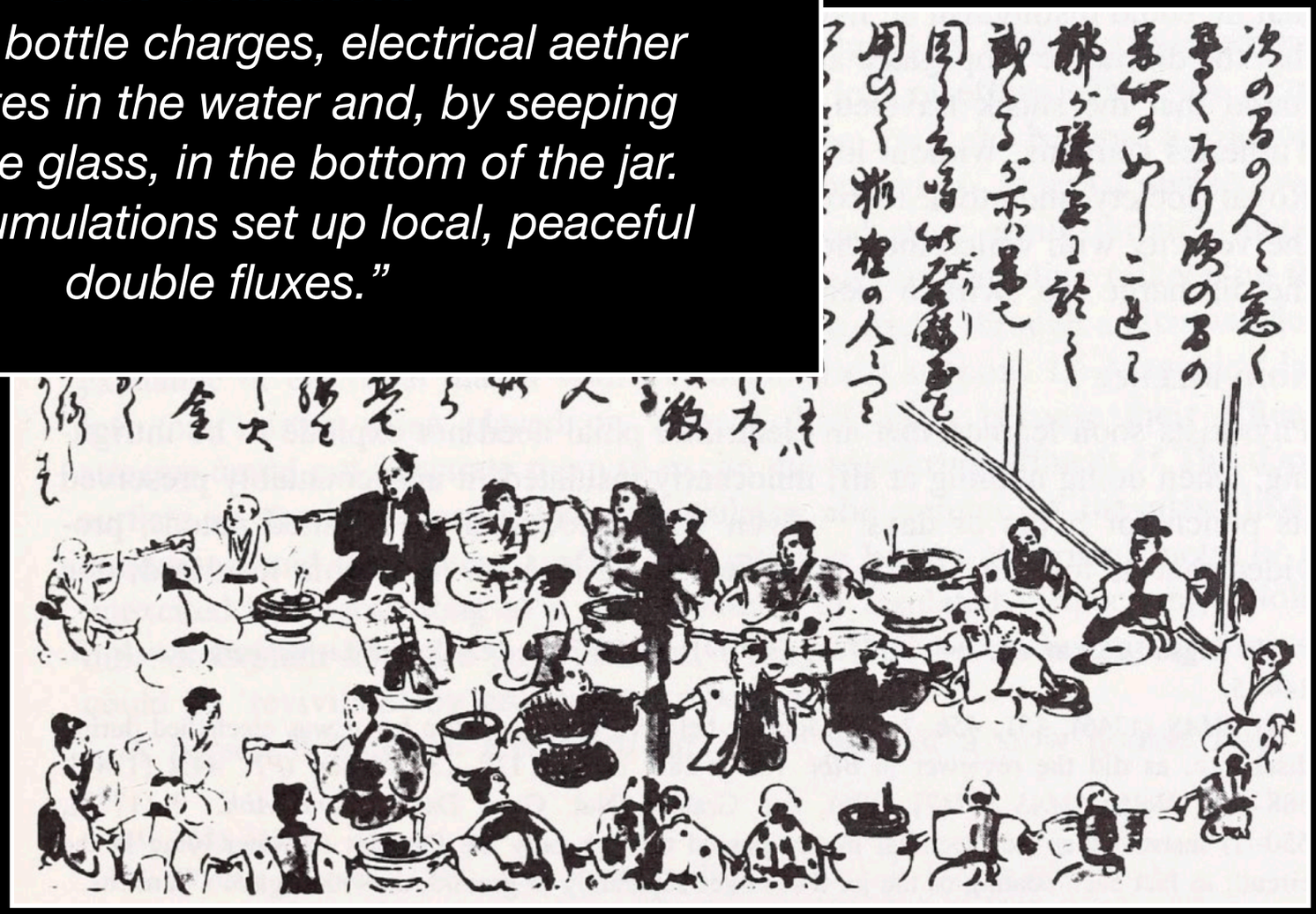

Benjamin Franklin and the Leyden Jar

"At the same time that the wire at the top of the bottle is electrised positively (or plus), the bottom of the bottle is electrised negatively (or minus), in exact proportion."

"Positive" = "Vitreous"

"Negative" = "Resinous"

Insulating pedestal ⟶

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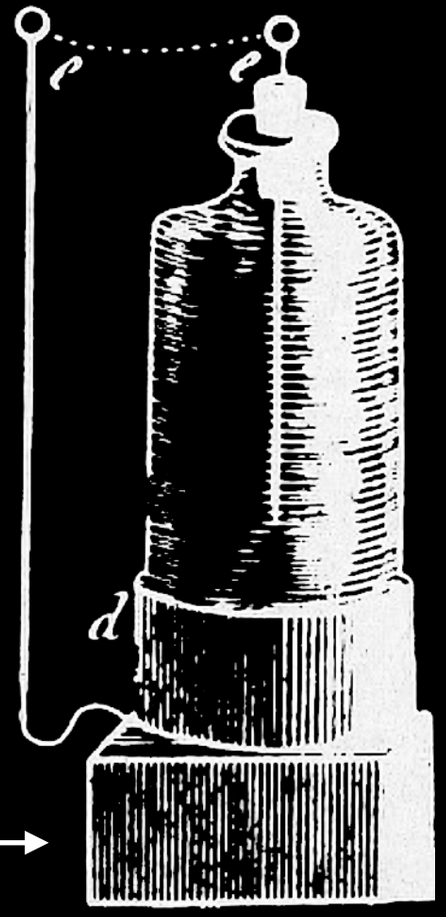
Cork on (insulating) silk thread

a.

"Tail wire"



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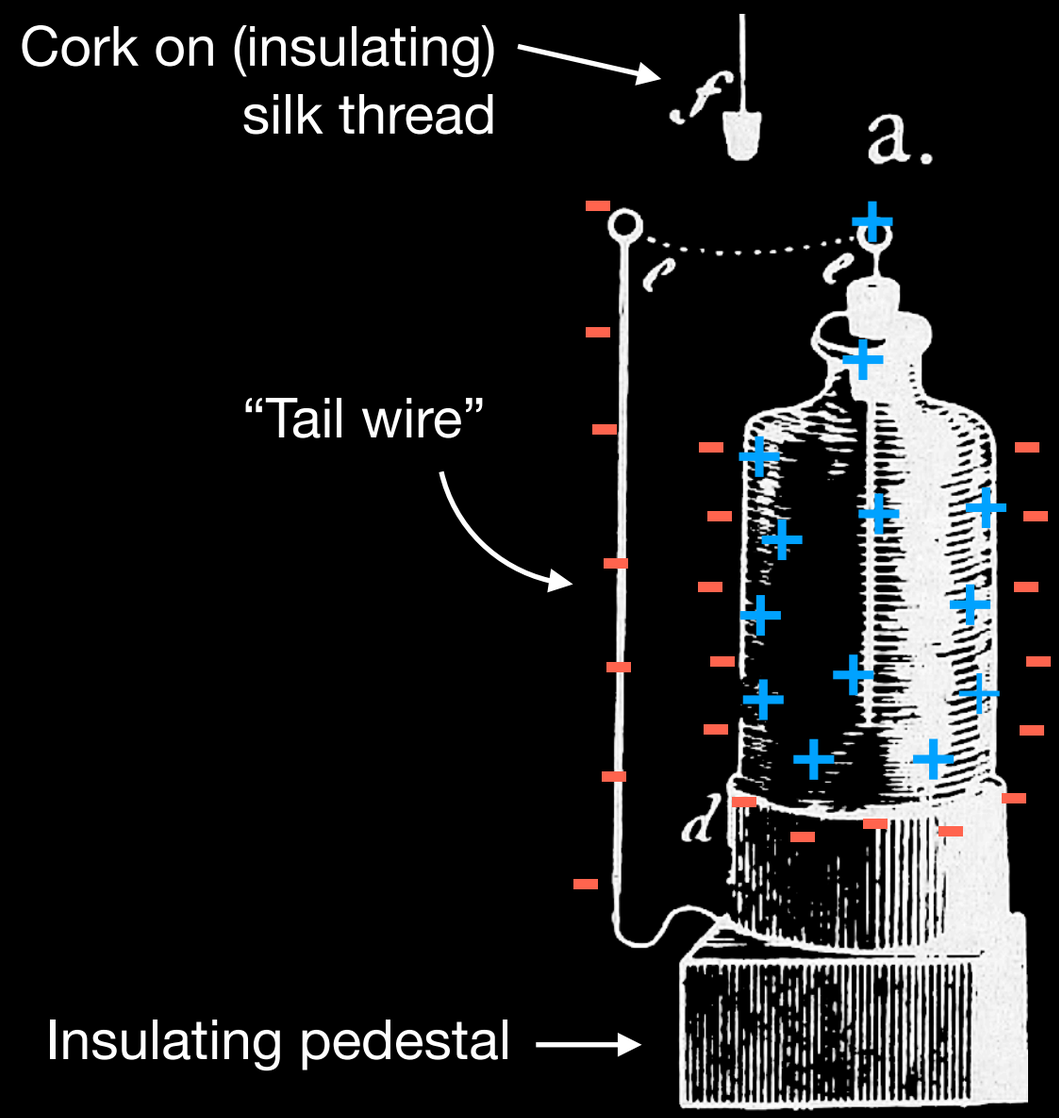

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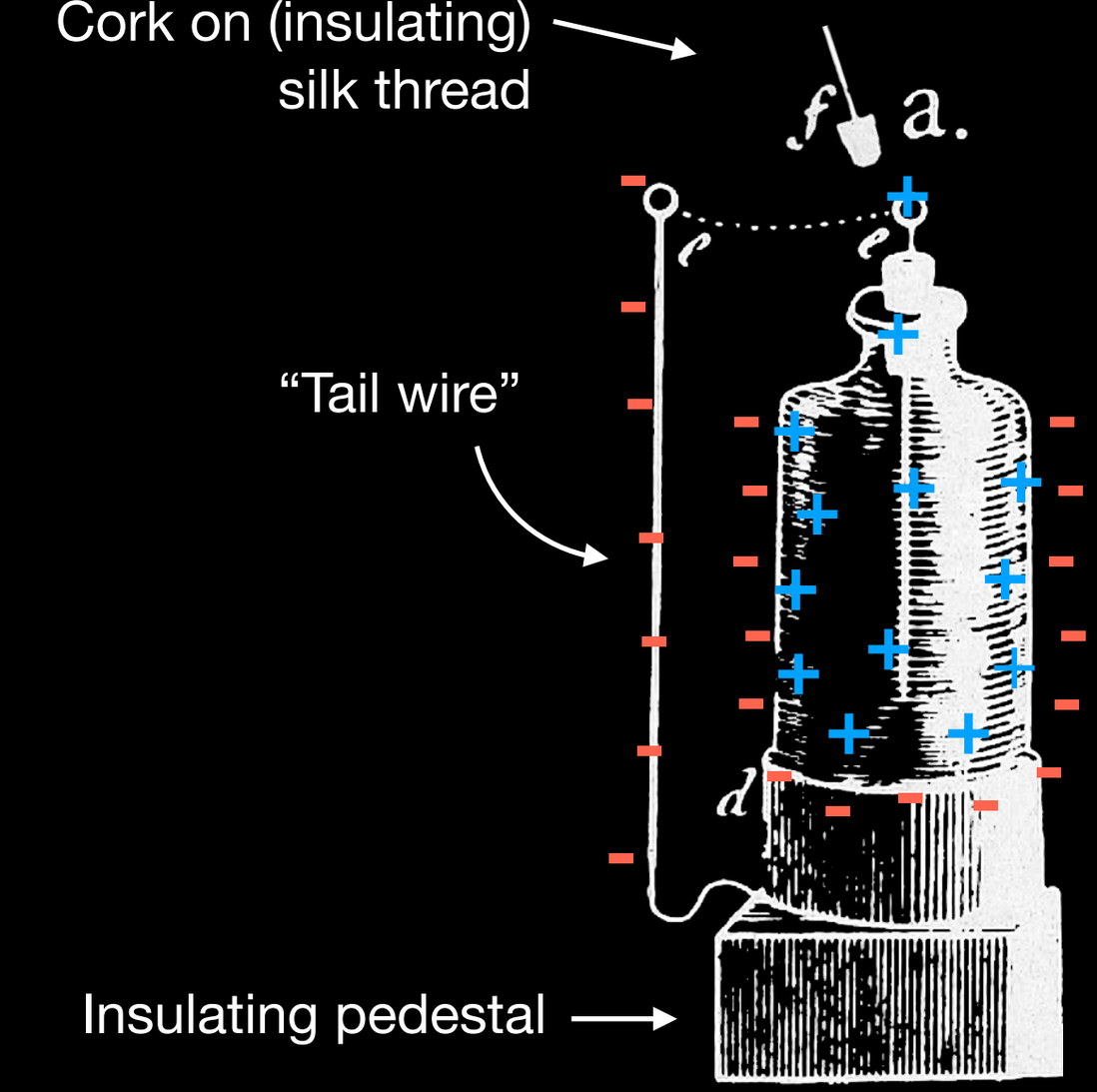

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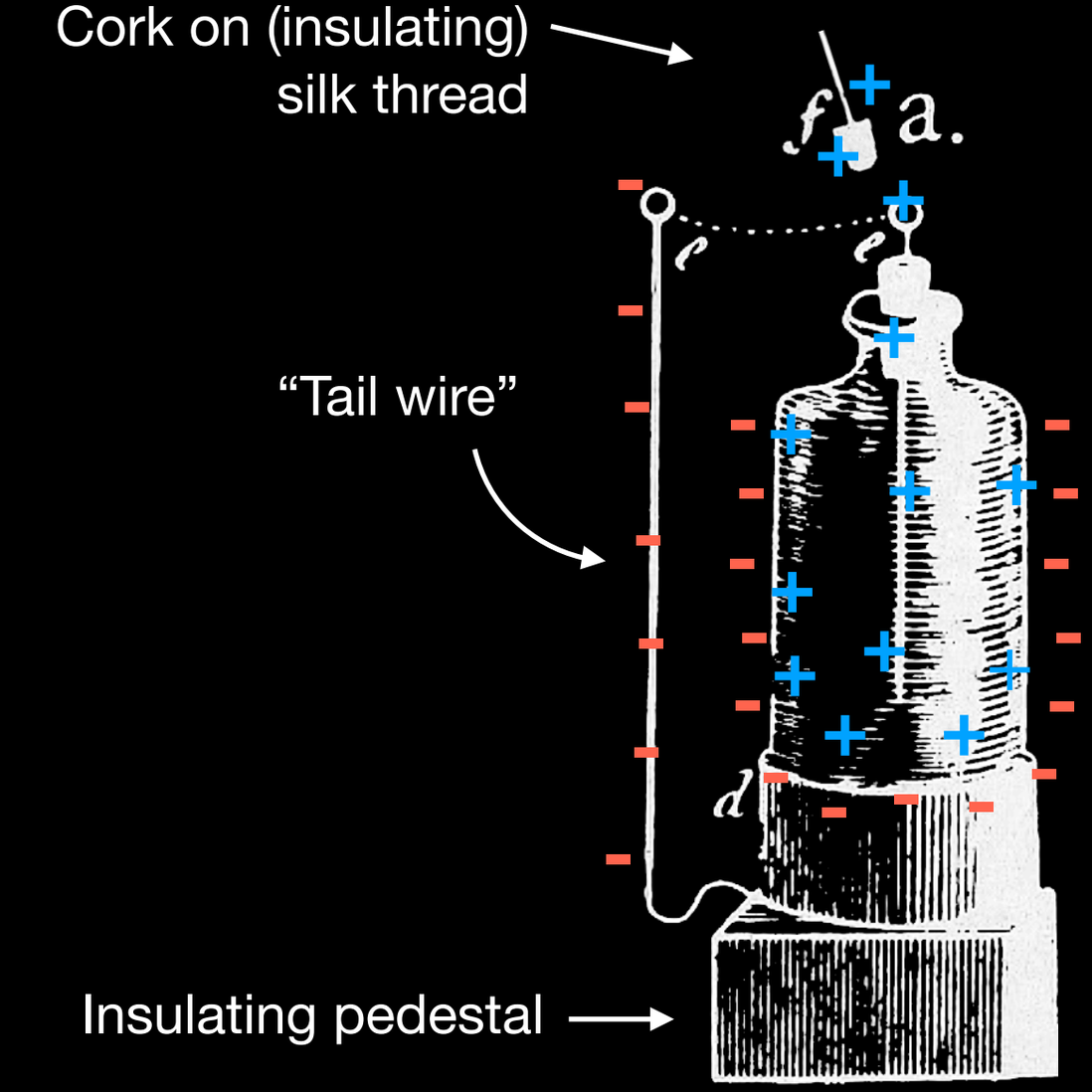

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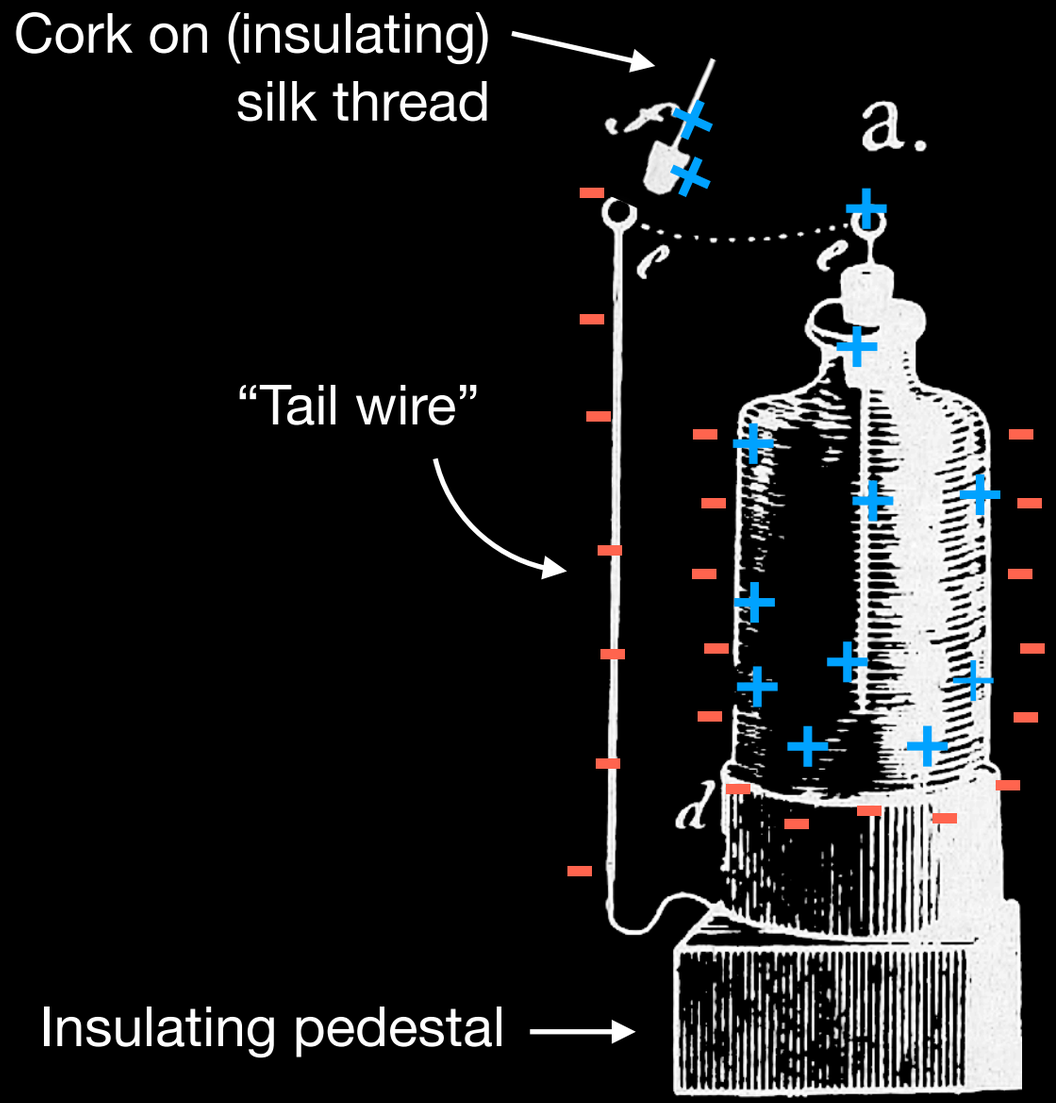

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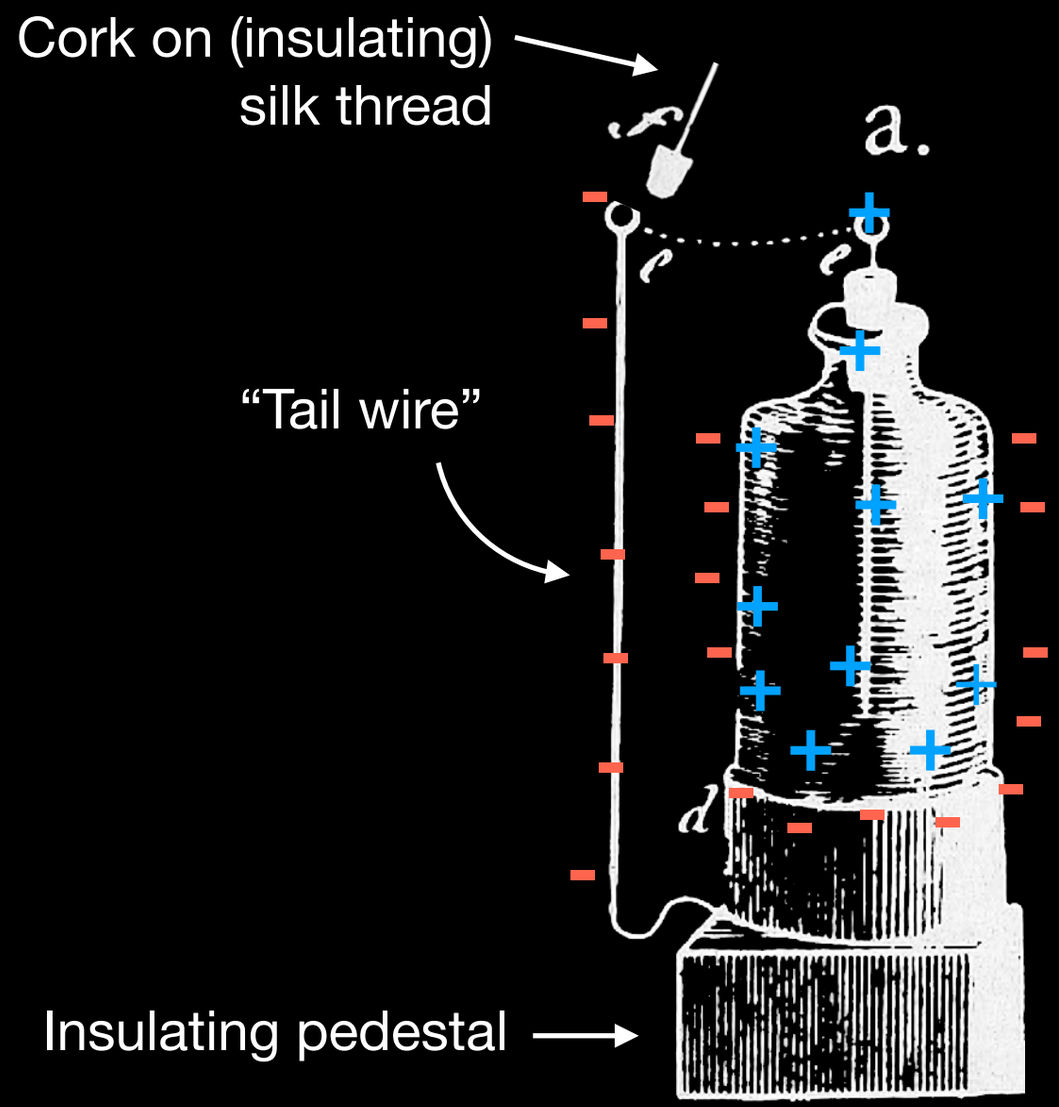

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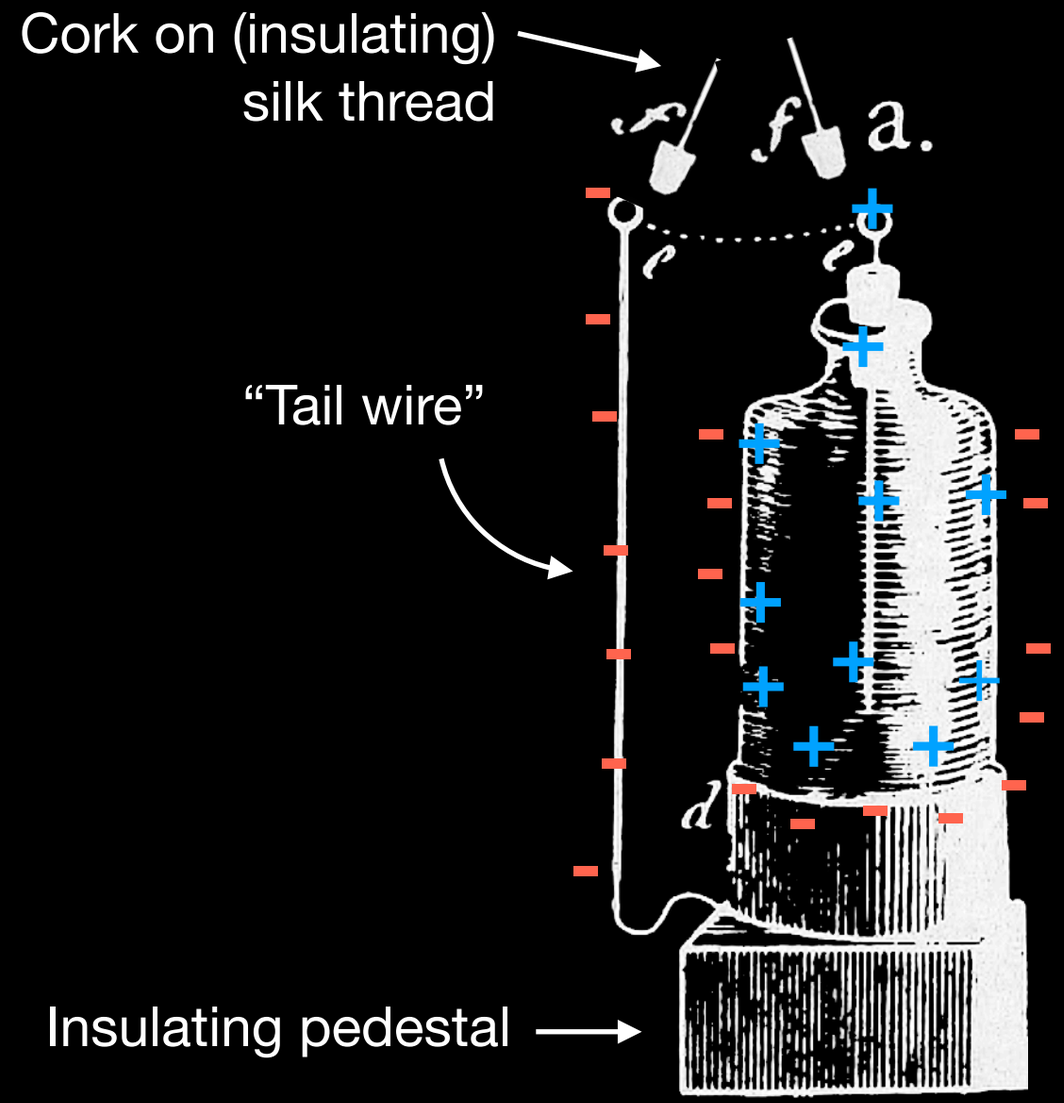
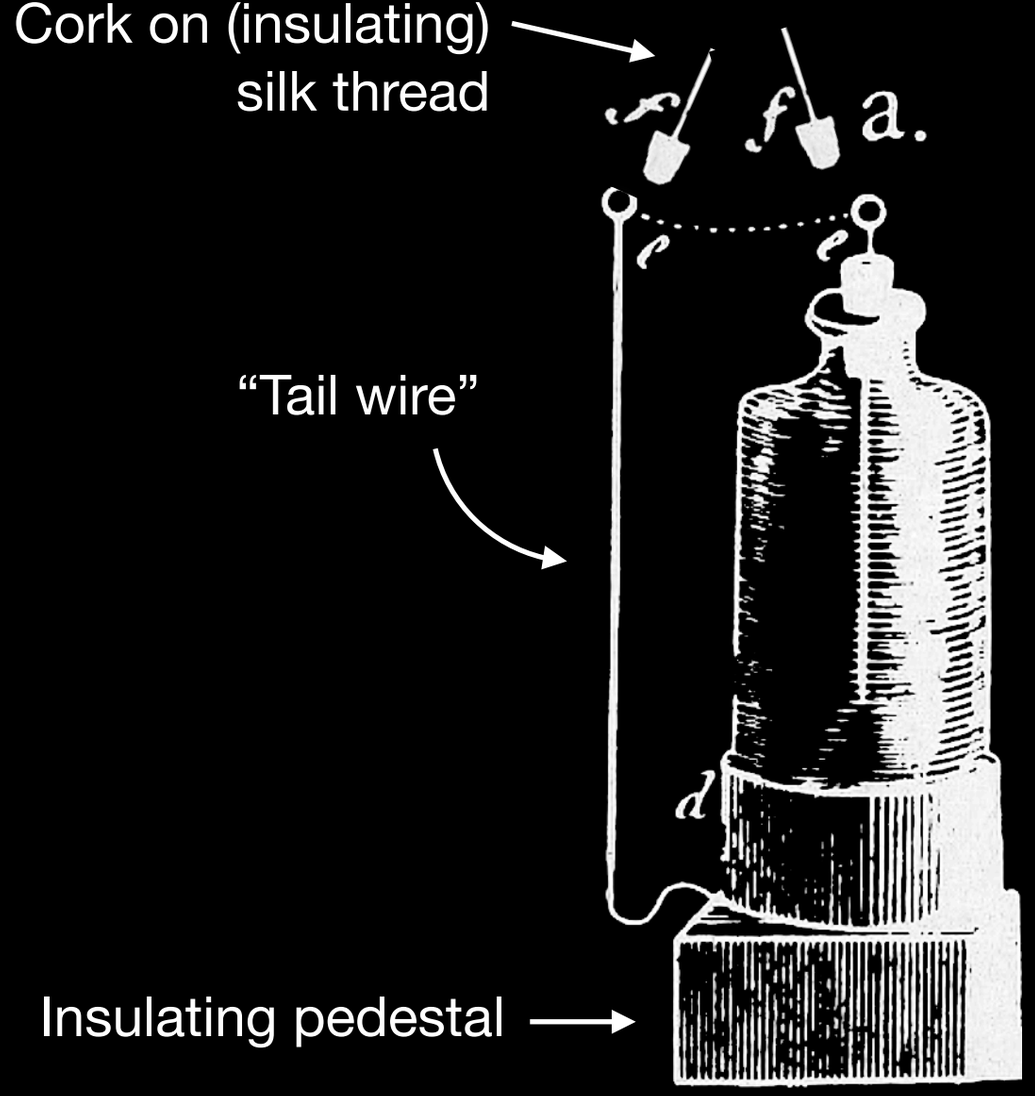


Benjamin Franklin and the Leyden Jar

"At the same time that the wire at the top of the bottle is electrised positively (or plus), the bottom of the bottle is electrised negatively (or minus), in exact proportion."

"Positive" = "Vitreous"

"Negative" = "Resinous"



The electricity fully disappears!

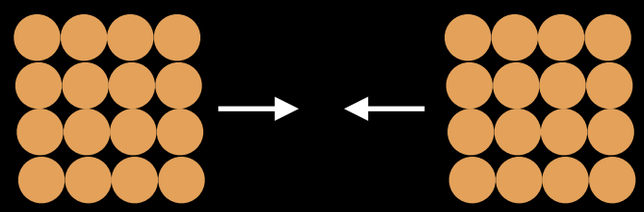
The nature of electricity …

… according to Benjamin Franklin

The nature of electricity …

… according to Benjamin Franklin

“Common matter”

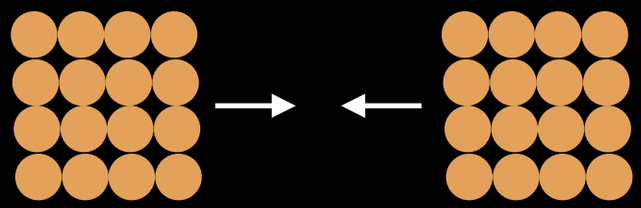


Mutually attracting

The nature of electricity …

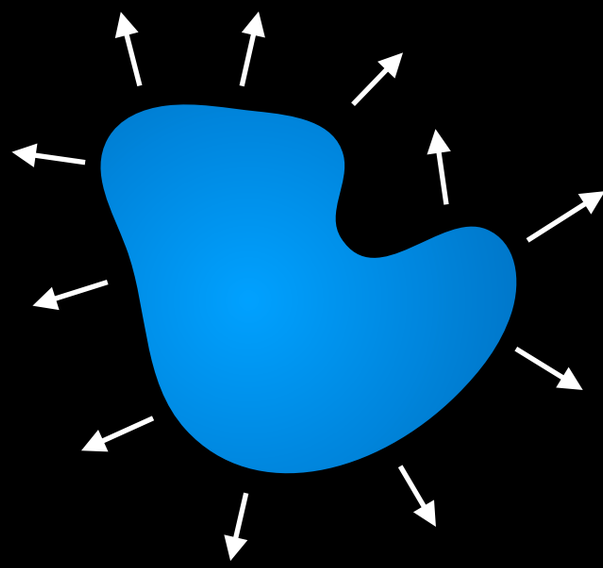
… according to Benjamin Franklin

“Common matter”



Mutually attracting

“Electrical matter”

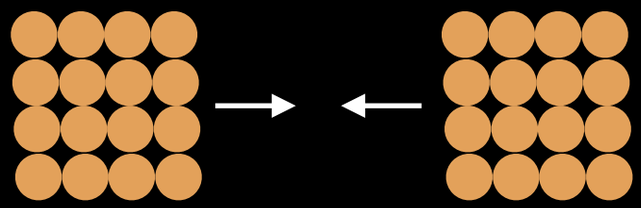


“Subtle fluid”,
mutually repelling

The nature of electricity …

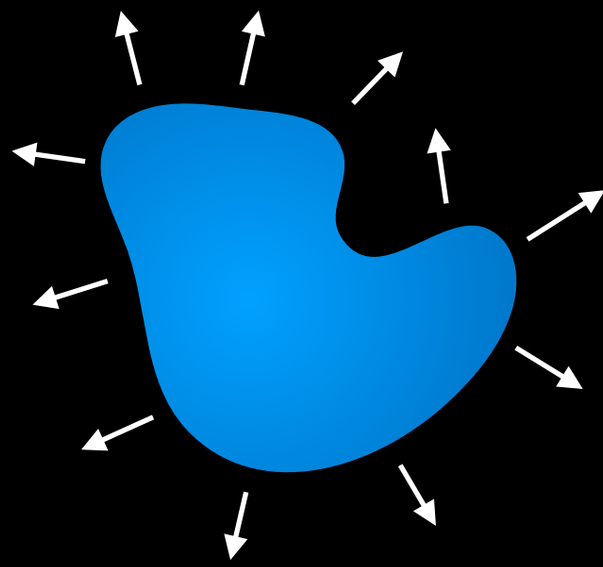
… according to Benjamin Franklin

“Common matter”



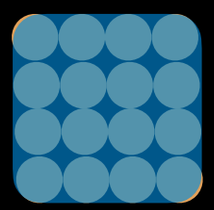
Mutually attracting

“Electrical matter”



“Subtle fluid”,
mutually repelling

“Neutral matter”

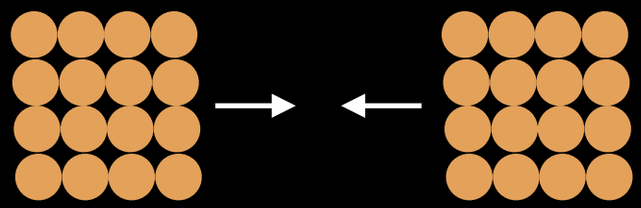


Common matter and electrical matter attract very strongly

The nature of electricity …

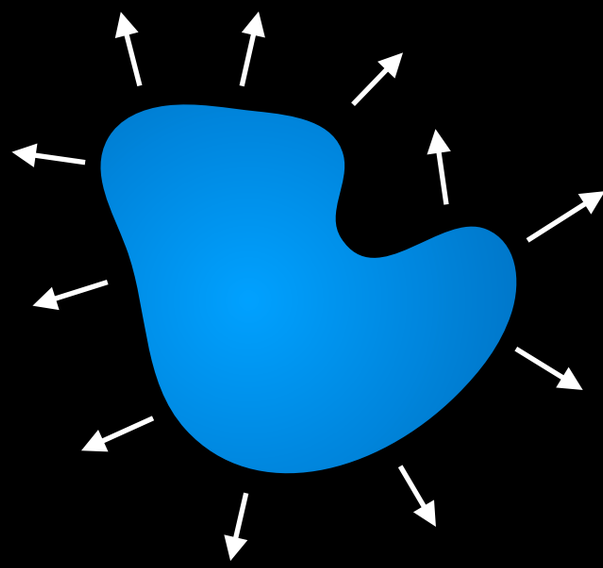
… according to Benjamin Franklin

“Common matter”



Mutually attracting

“Electrical matter”

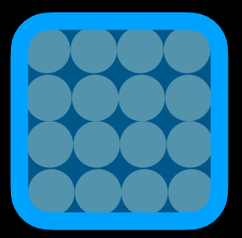


“Subtle fluid”, mutually repelling

“Neutral matter”

Common matter and electrical matter attract very strongly

Electrically charged matter



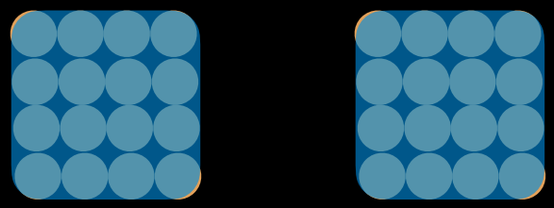
Electrical matter forms “atmosphere” on surface of body

The nature of electricity …

… according to Benjamin Franklin

The nature of electricity …

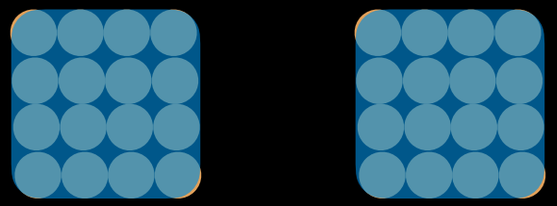
… according to Benjamin Franklin



Two neutral bodies do not attract nor repel

The nature of electricity …

… according to Benjamin Franklin

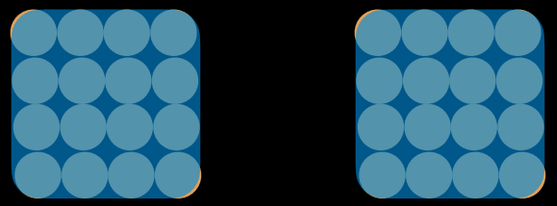


Two neutral bodies do not attract nor repel

The atmospheres of two (positively) electrised bodies repel

The nature of electricity …

… according to Benjamin Franklin



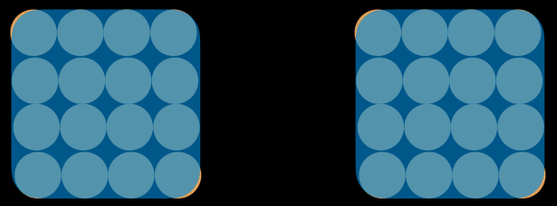
Two neutral bodies do not attract nor repel

The atmospheres of two (positively) electrised bodies repel

“It seems absurd to suppose that a body can act where it is not.

The nature of electricity …

… according to Benjamin Franklin



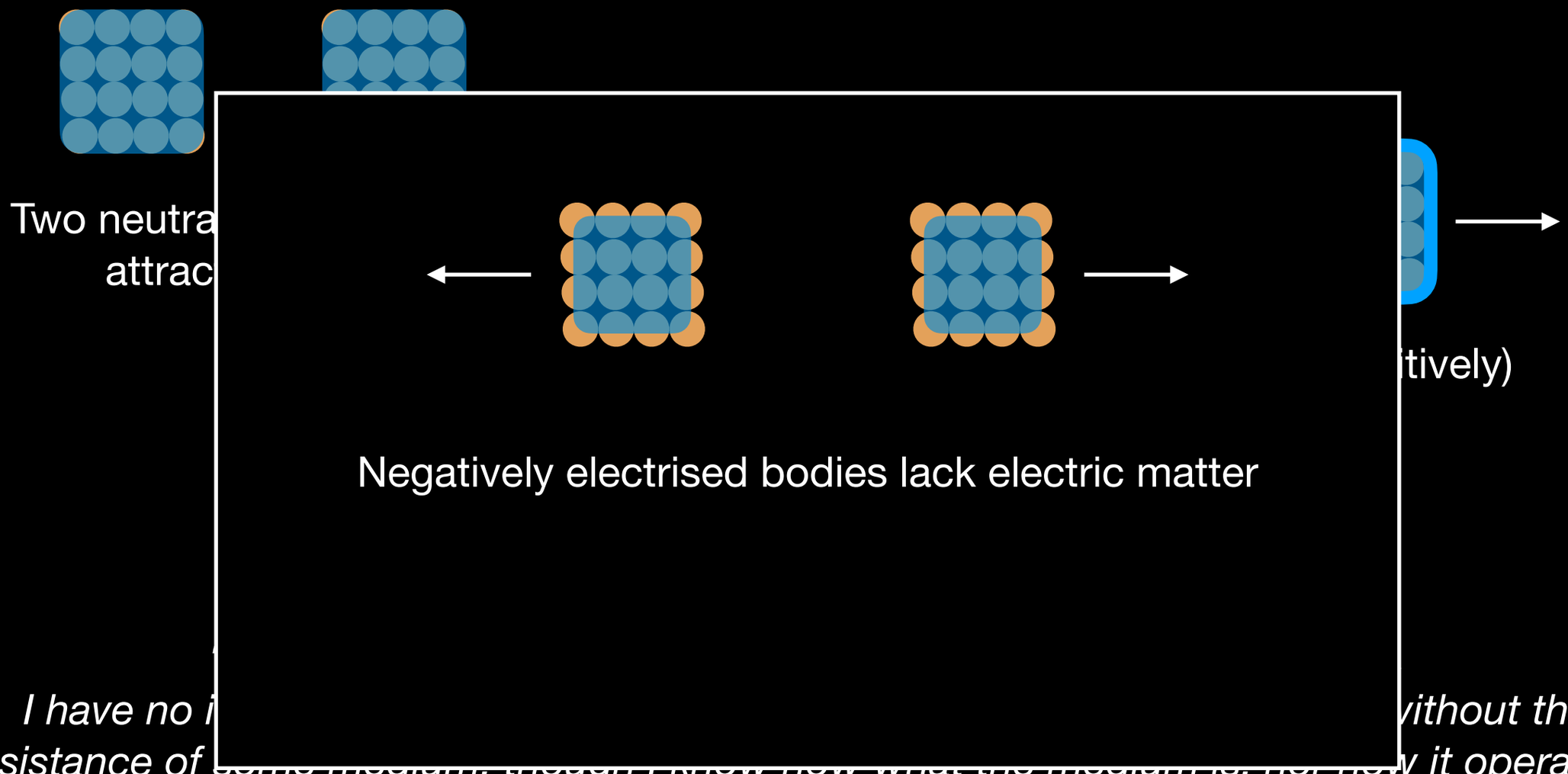
Two neutral bodies do not attract nor repel

The atmospheres of two (positively) electrised bodies repel

“It seems absurd to suppose that a body can act where it is not. I have no idea of bodies at a distance attracting or repelling one another without the assistance of some medium, though I know now what the medium is, nor how it operates.”

The nature of electricity …

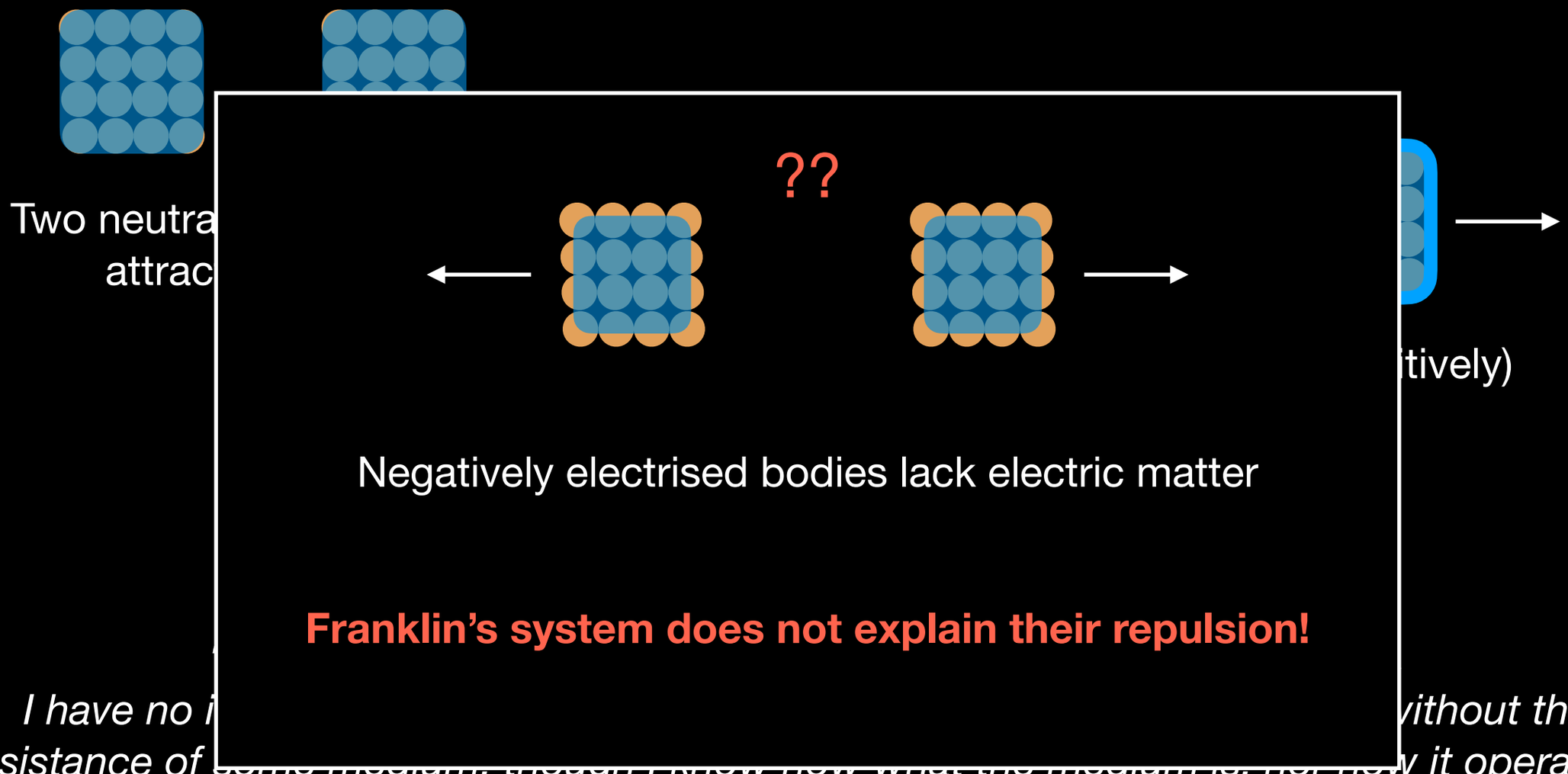
… according to Benjamin Franklin



I have no i *vithout the assistance of some medium, though I know how what the medium is, nor how it operates.”*

The nature of electricity …

… according to Benjamin Franklin



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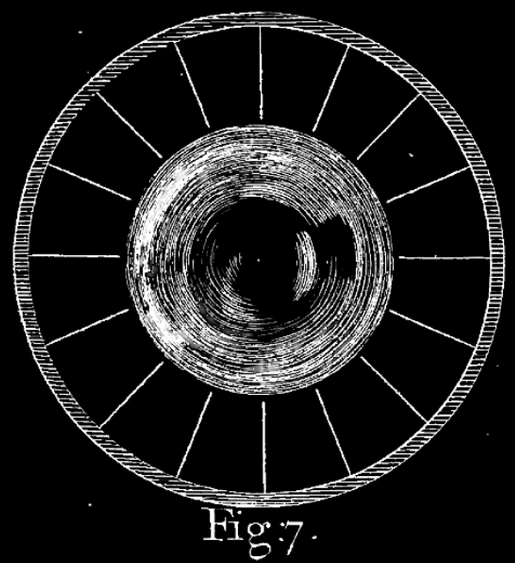
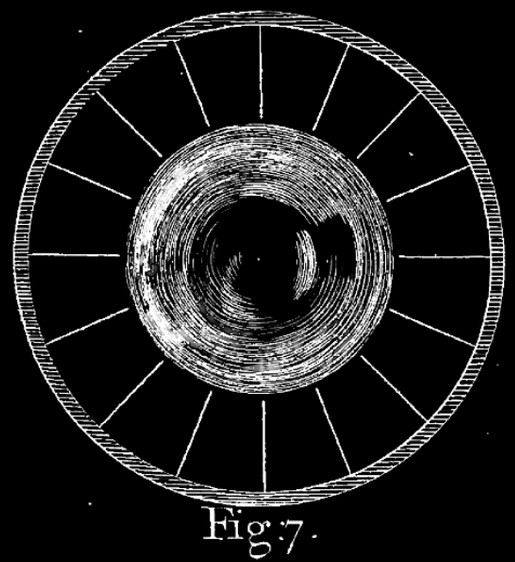
The nature of electricity

The nature of electricity

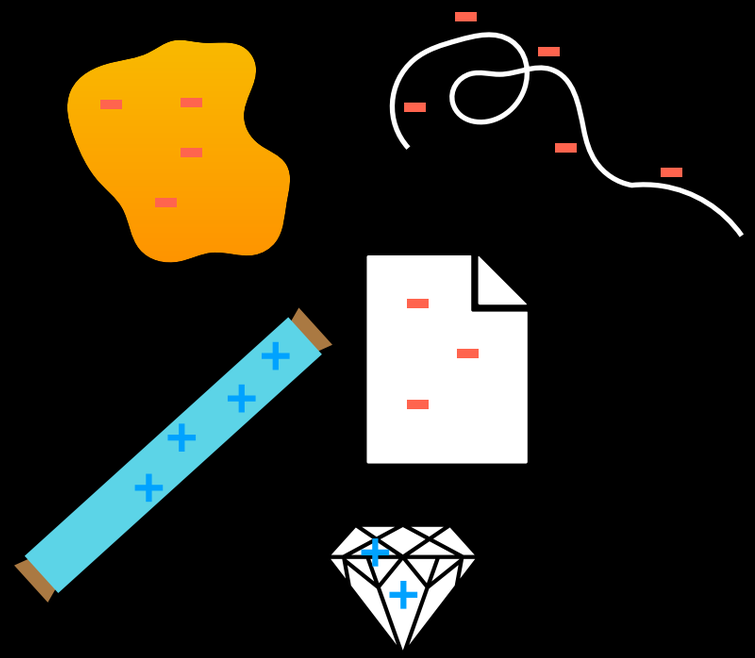


Gilbert's and Hauksbee's "Effluvia"

The nature of electricity

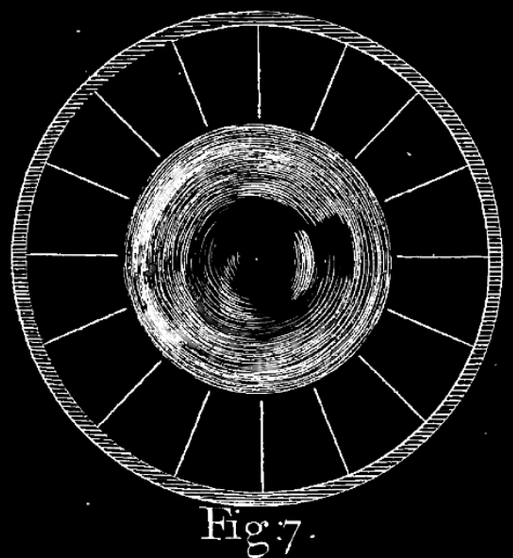


Gilbert's and Hauksbee's "Effluvia"

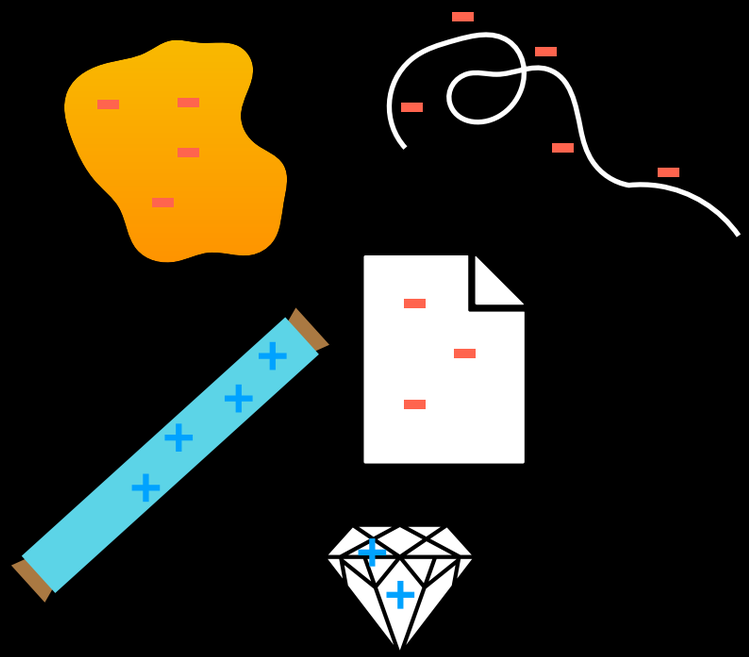


Du Fay's two kinds of "electrick"

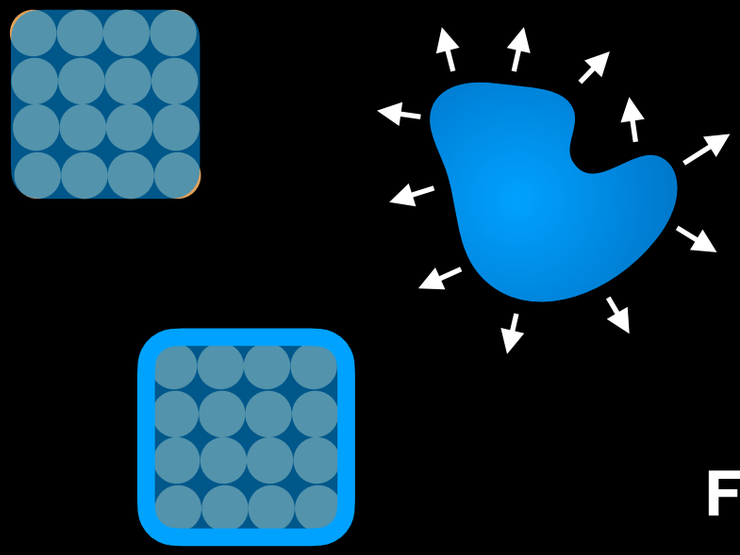
The nature of electricity



Gilbert's and Hauksbee's "Effluvia"



Du Fay's two kinds of "electrick"

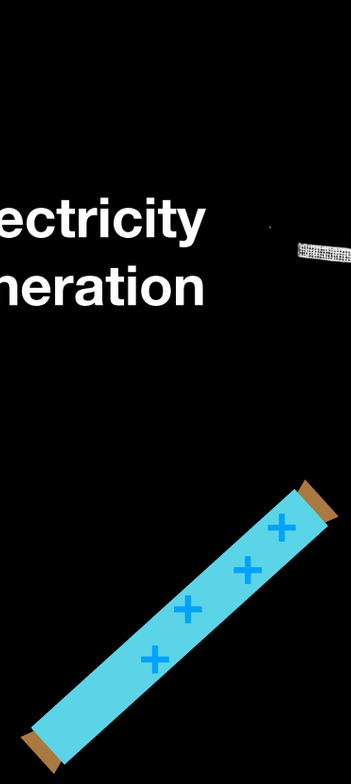


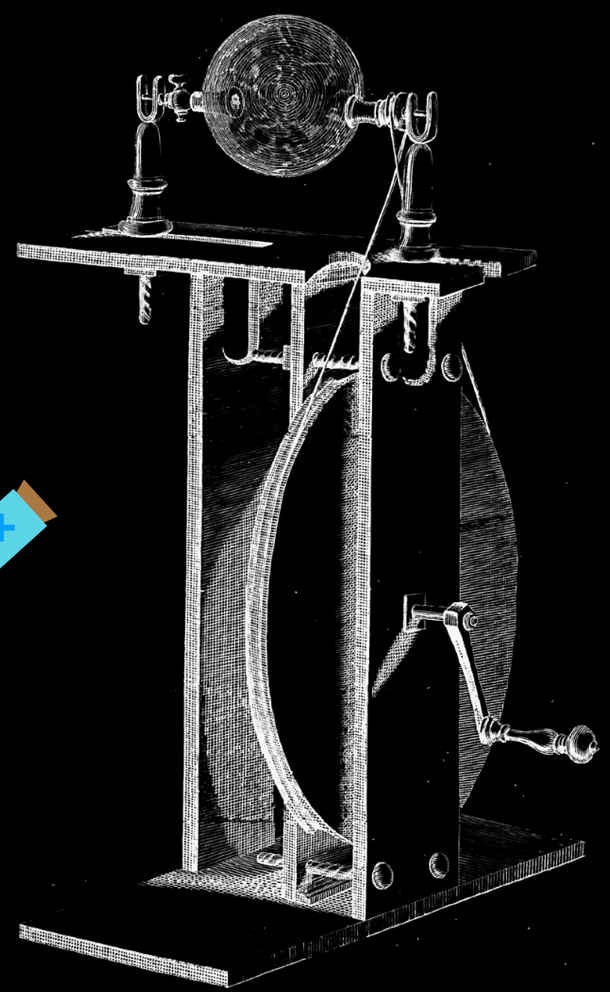
Franklin's "electric atmospheres"

Taming electricity

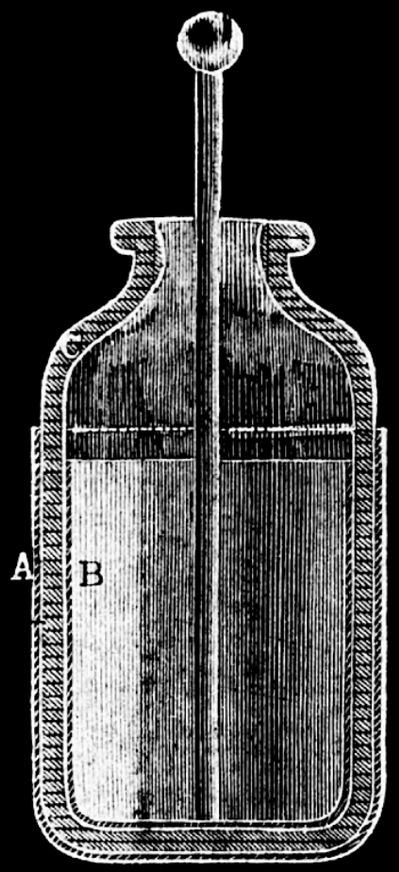
Taming electricity

Electricity generation



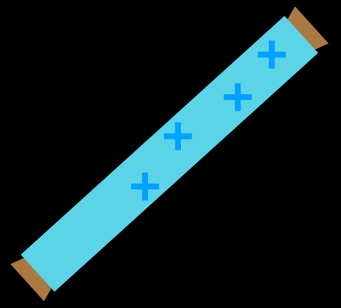


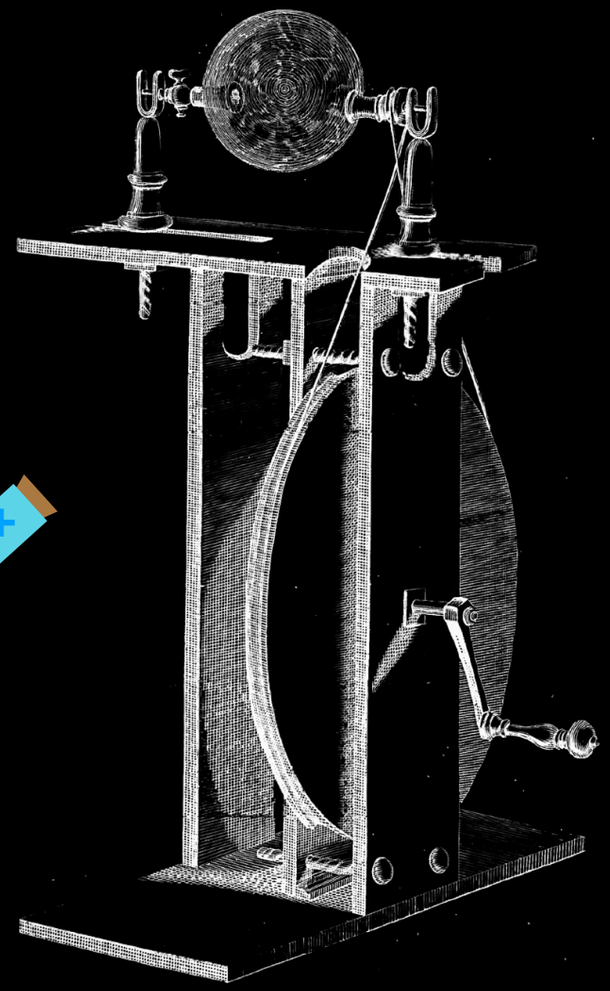
Taming electricity



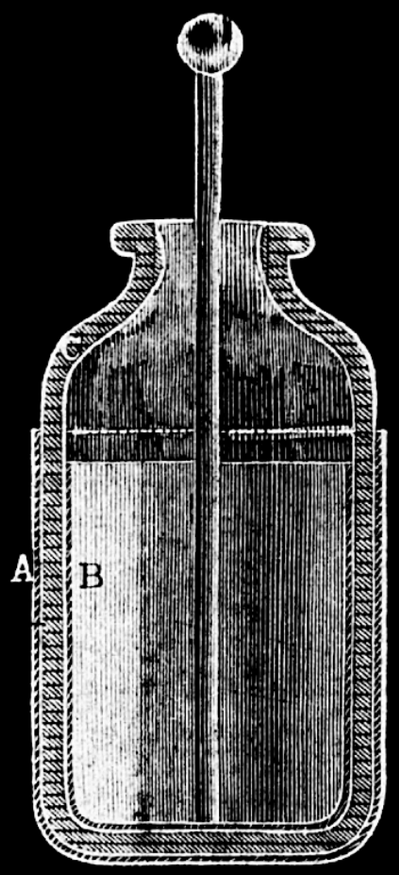
Electricity “amplification”
(storage)

Electricity generation





Taming electricity



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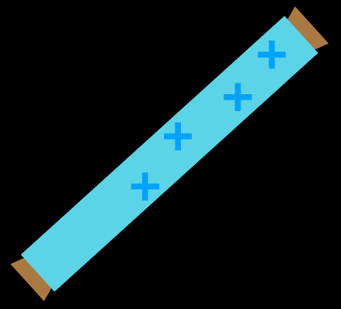
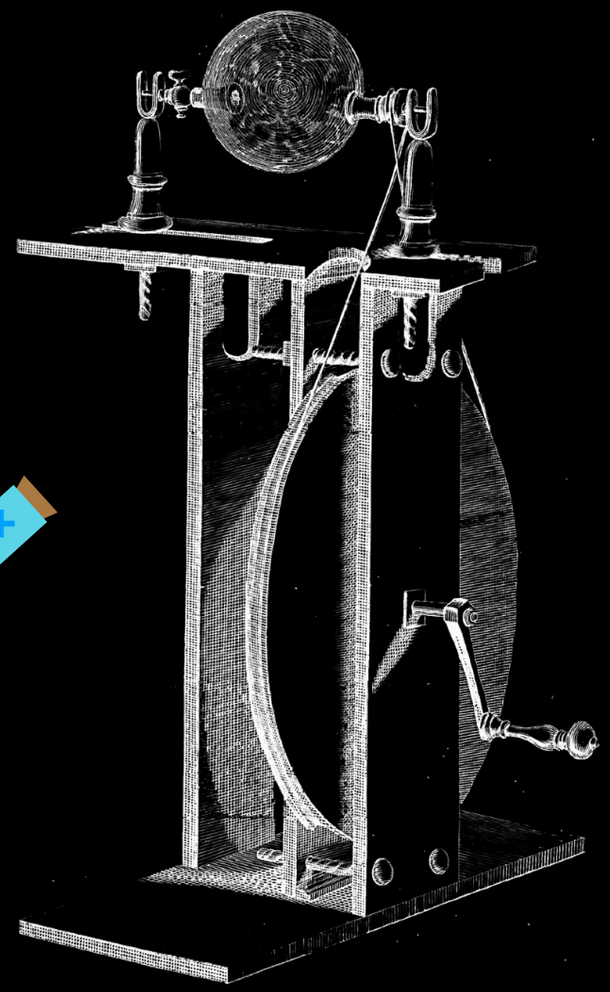
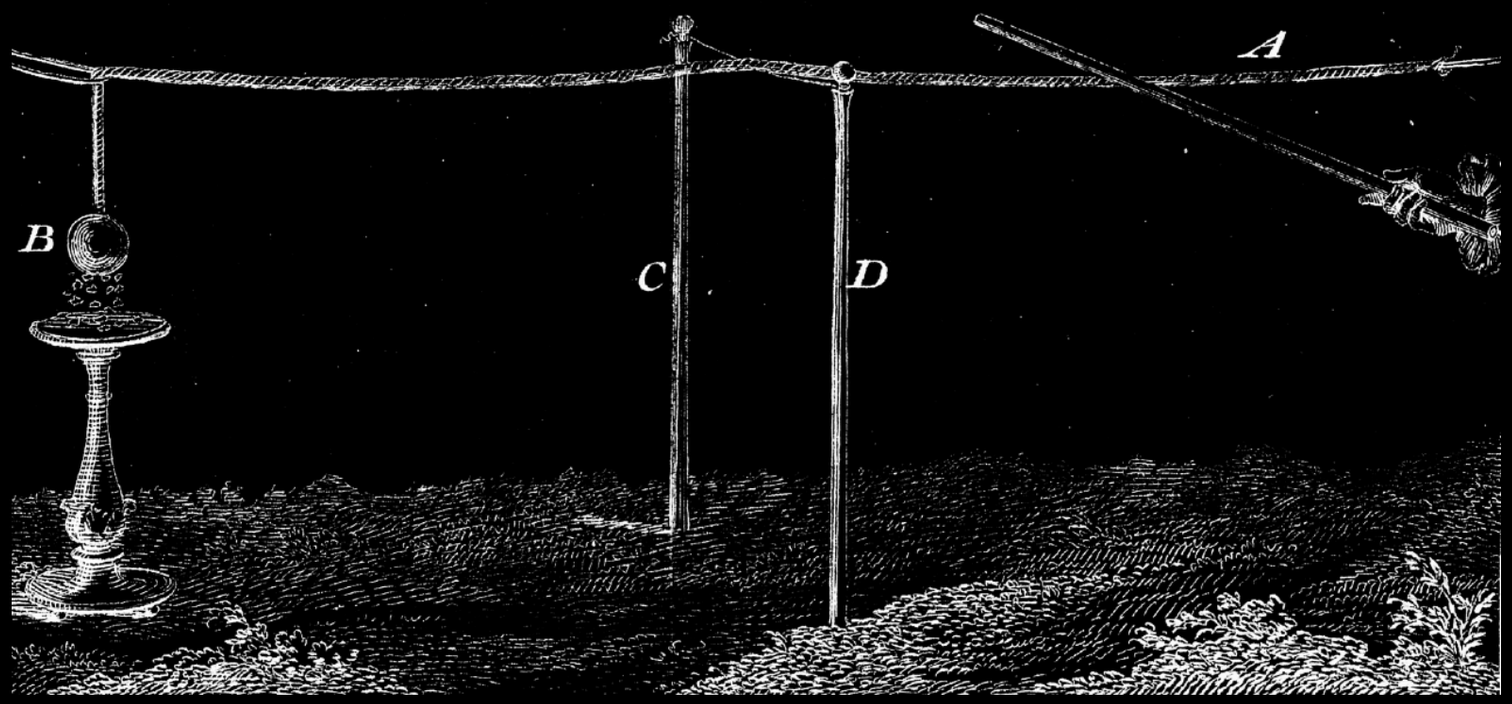
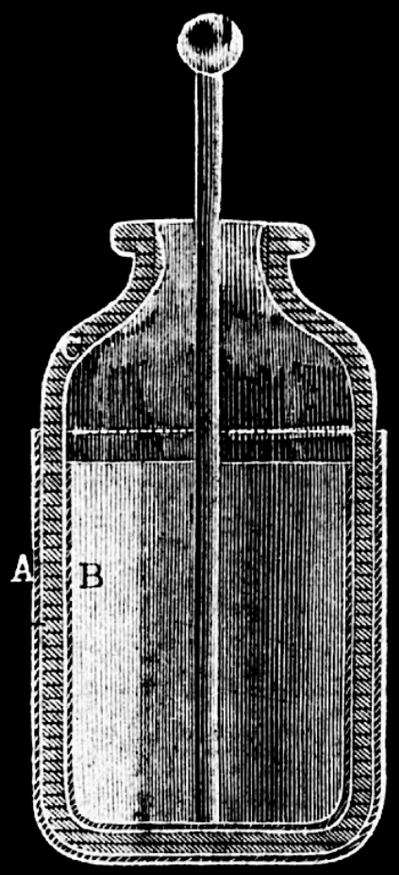




Electricity “communication”



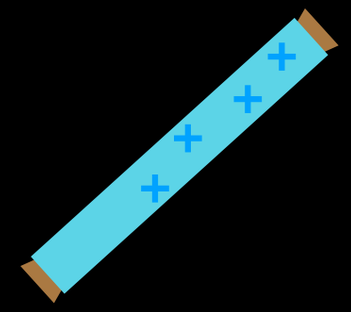
Taming electricity

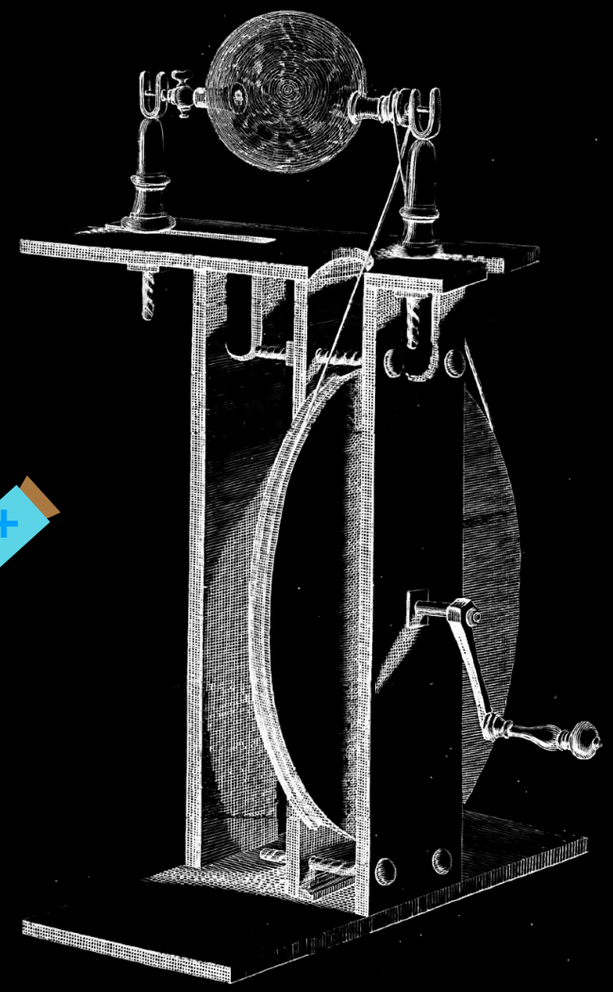


Electricity
“amplification”
(storage)

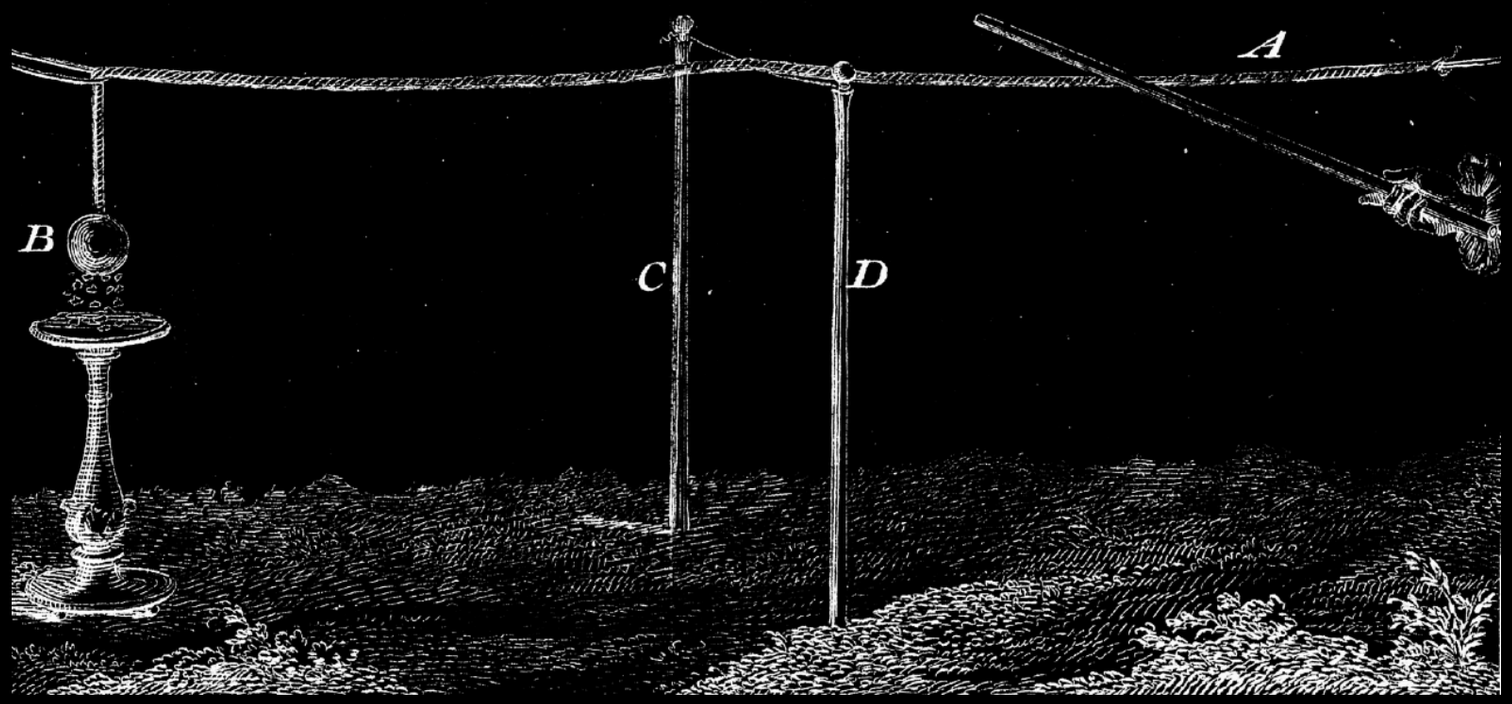
No “applications” yet!
Some ingredients are still missing …

Electricity
generation



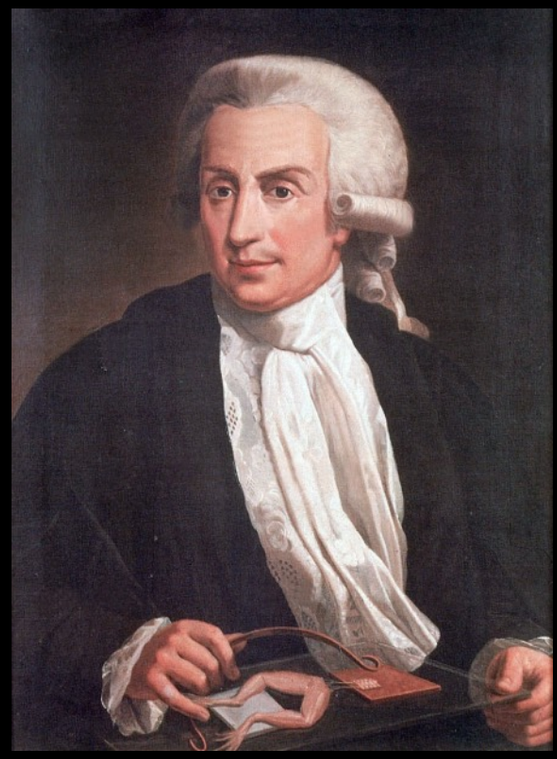


Electricity “communication”



Luigi Galvani

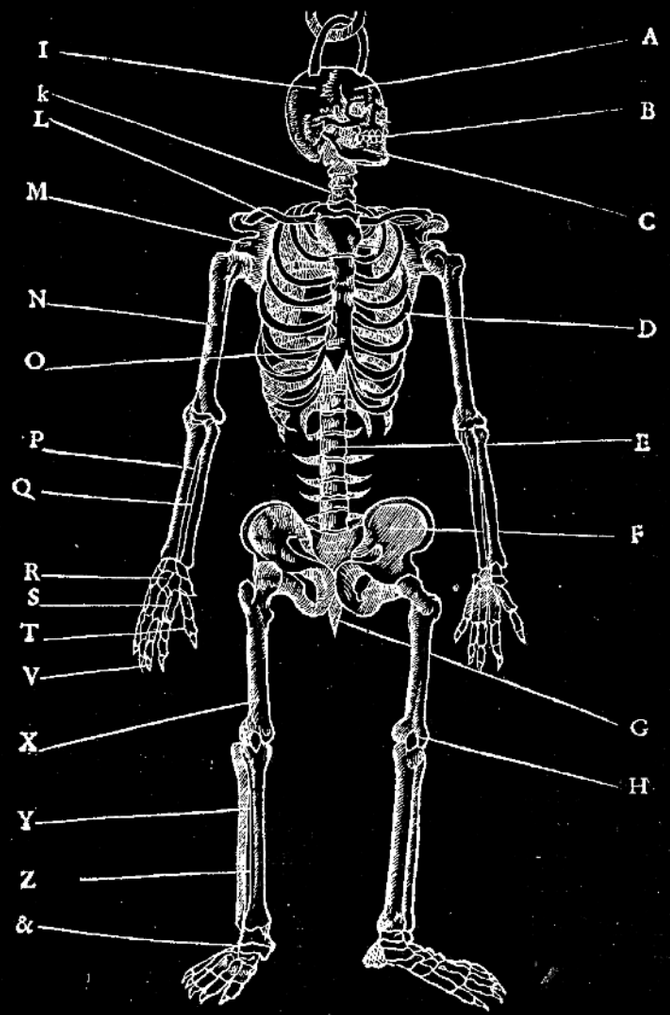
Anatomist, lecturer at University of Bologna



“Comparative anatomy”

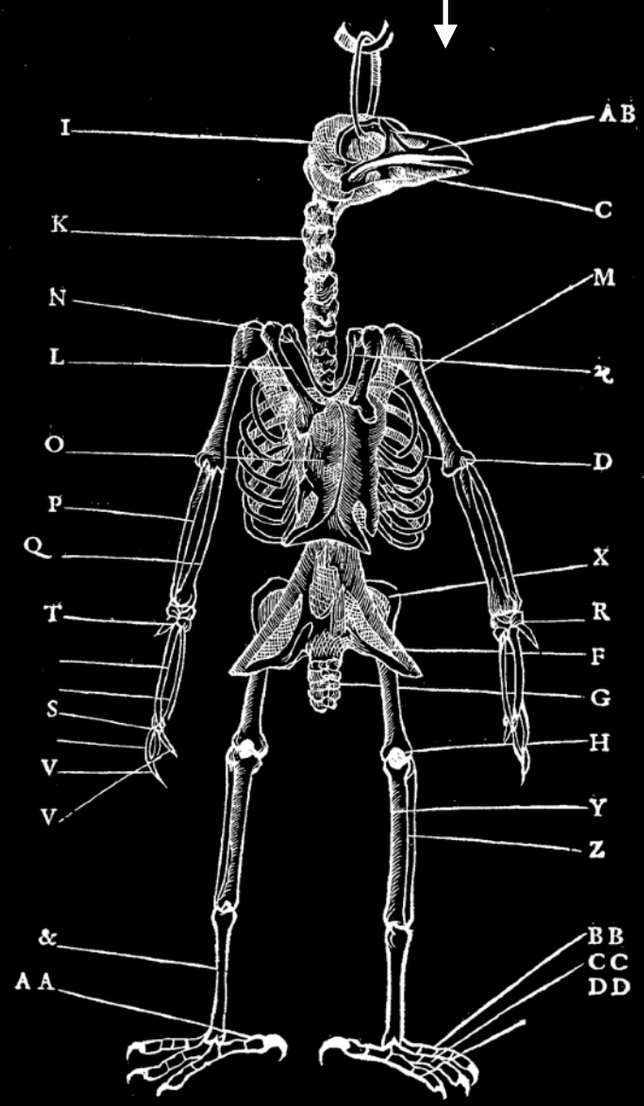
Luigi Galvani

Anatomist, lecturer at University of Bologna



Human

Bird



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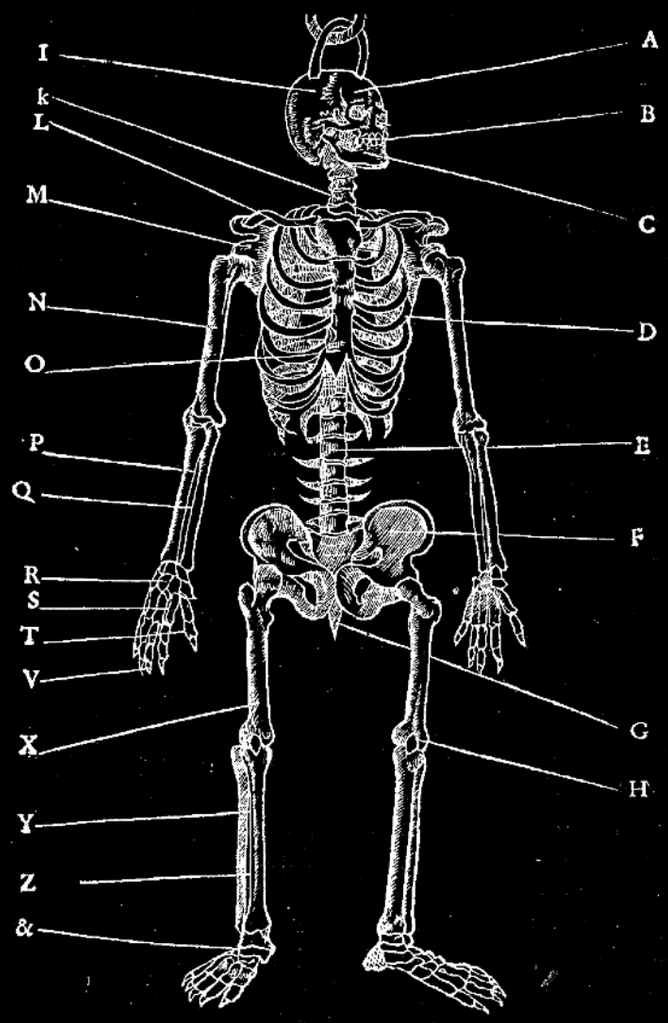
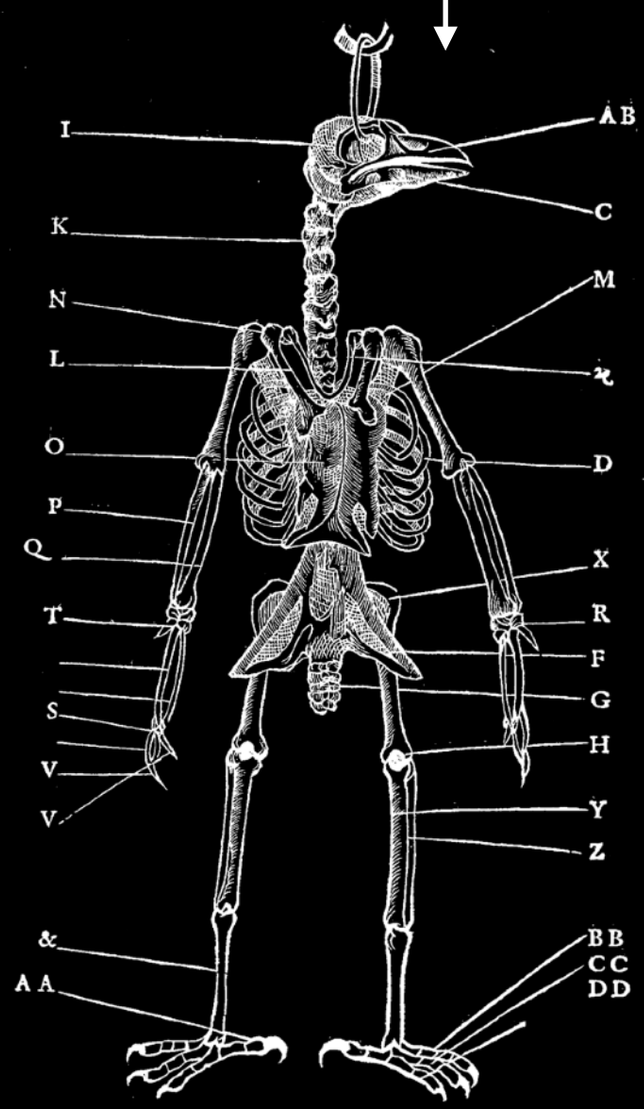
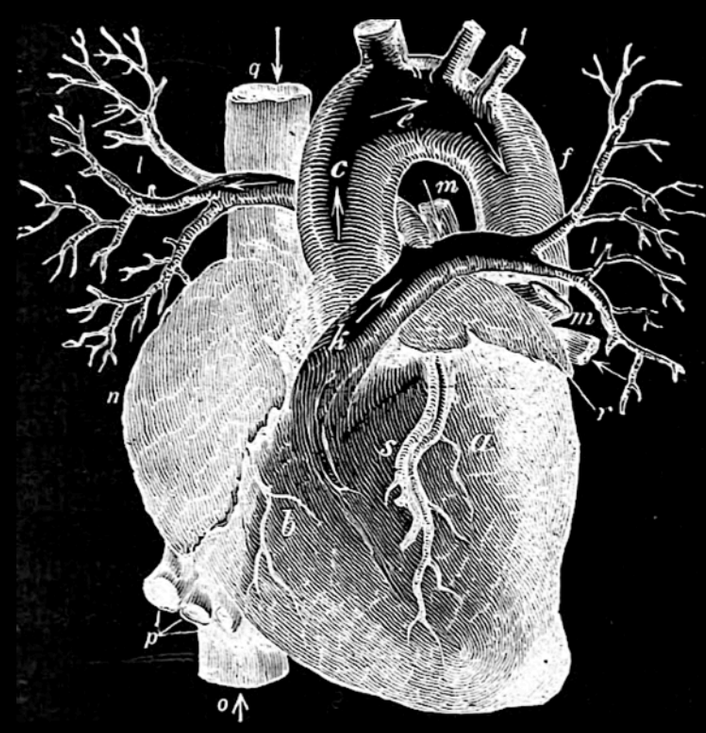


Human

Bird



"Comparative anatomy"



Physiology

Frogs and “animal electricity”

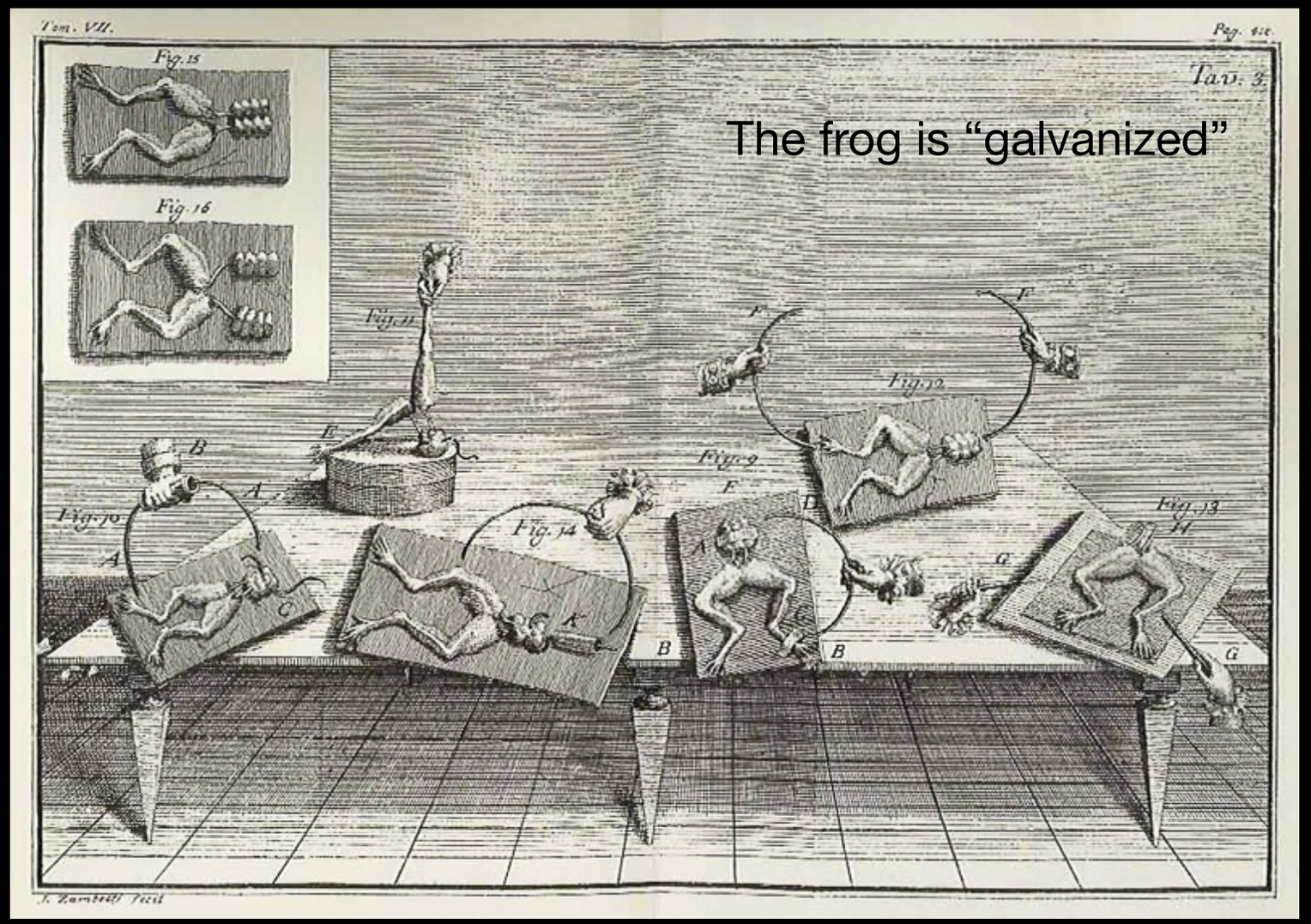
1791:

“Prepared frogs, which were fastened by brass hooks in their spinal cord to an iron railing which surrounded a certain hanging garden of my house, fell into contractions.”

Frogs and “animal electricity”

Galvani tries a more controlled experiment:

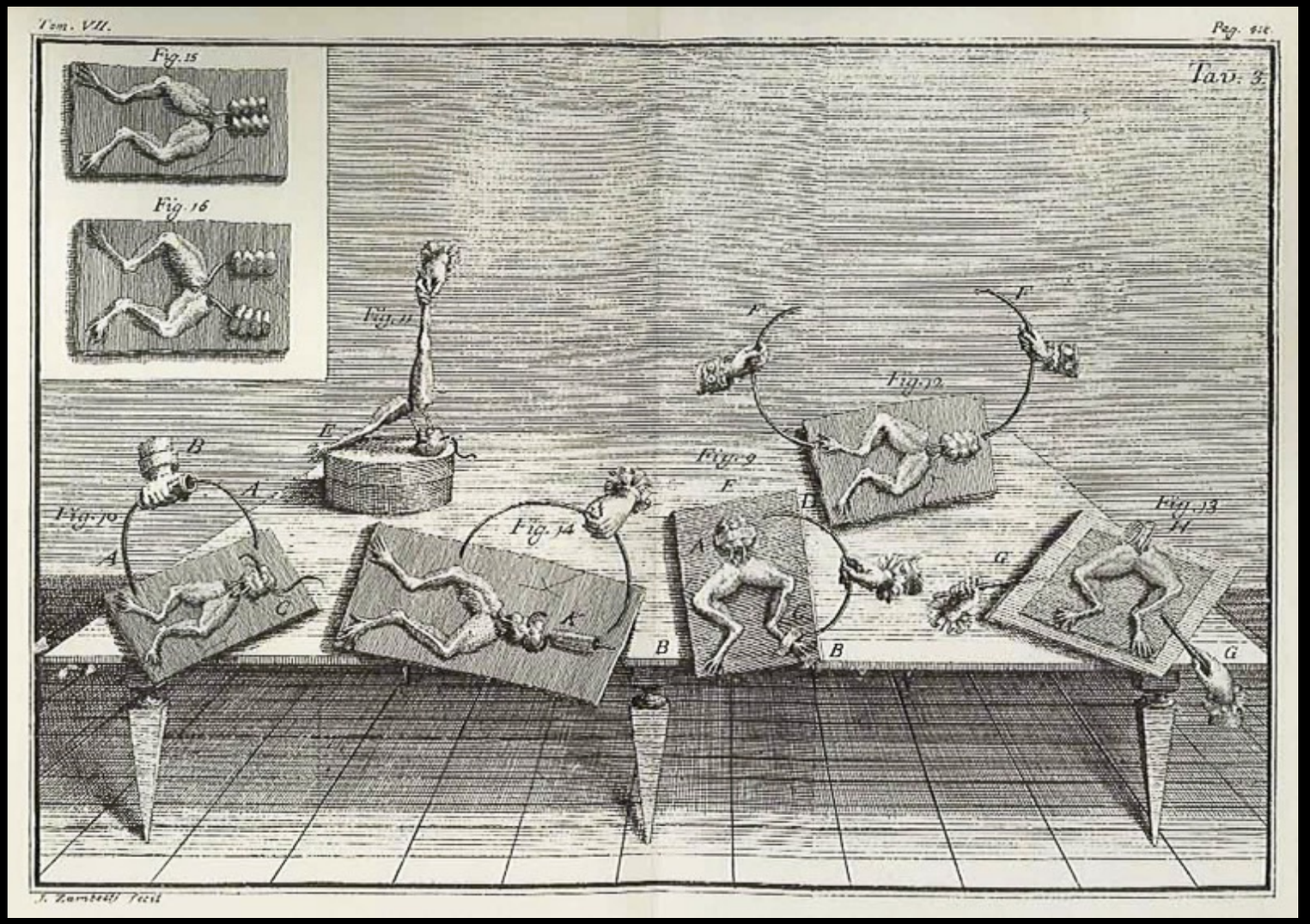
“When I brought the animal into a closed room, placed it on an iron plate, and began to press the hook with which it was fastened in the spinal cord against the plate, behold!, the same contractions occurred as before.”



Frogs and “animal electricity”

Galvani tries a more controlled experiment:

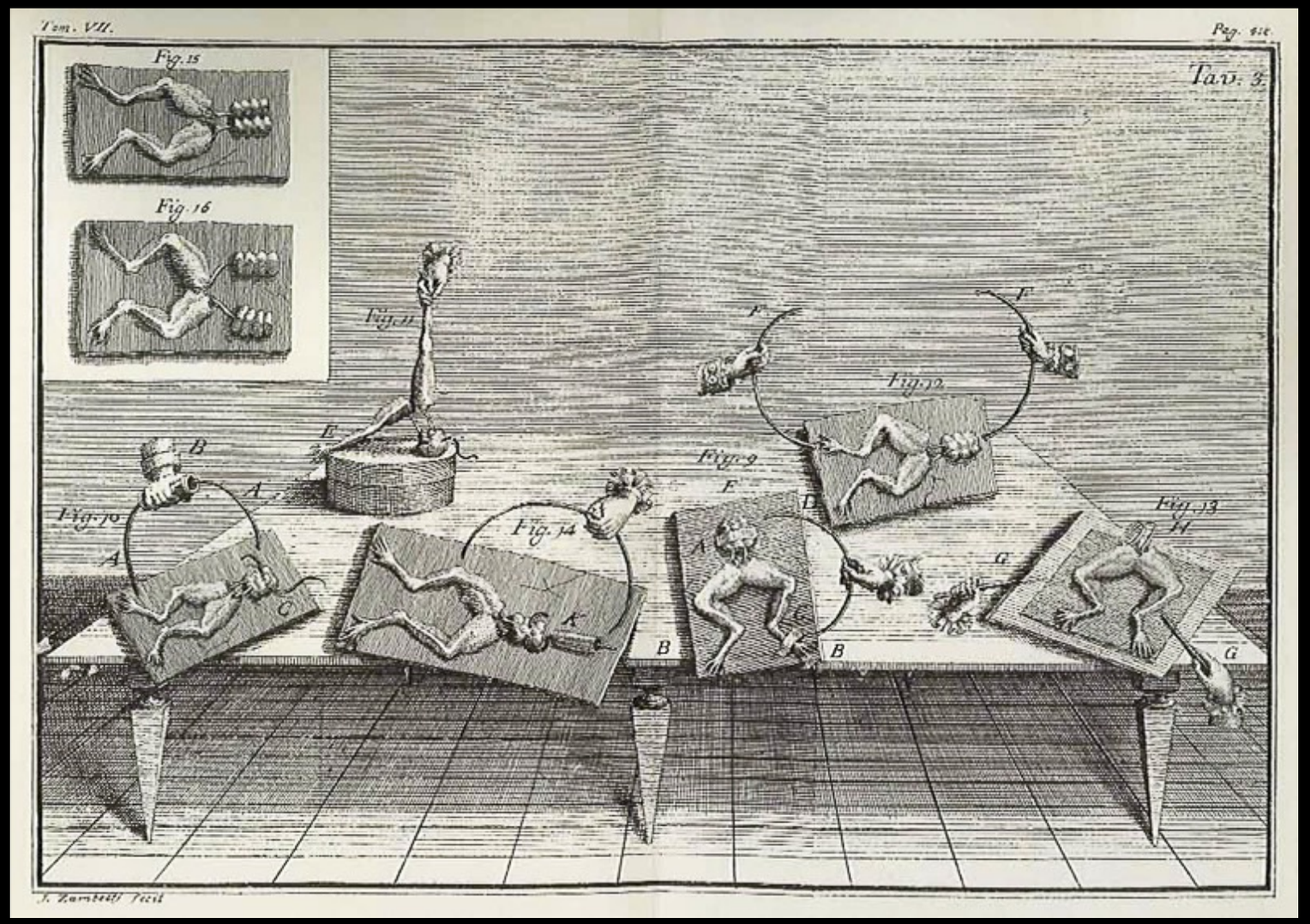
“I immediately repeated the experiment in different places with different metals and at different hours of the day.



Frogs and “animal electricity”

Galvani tries a more controlled experiment:

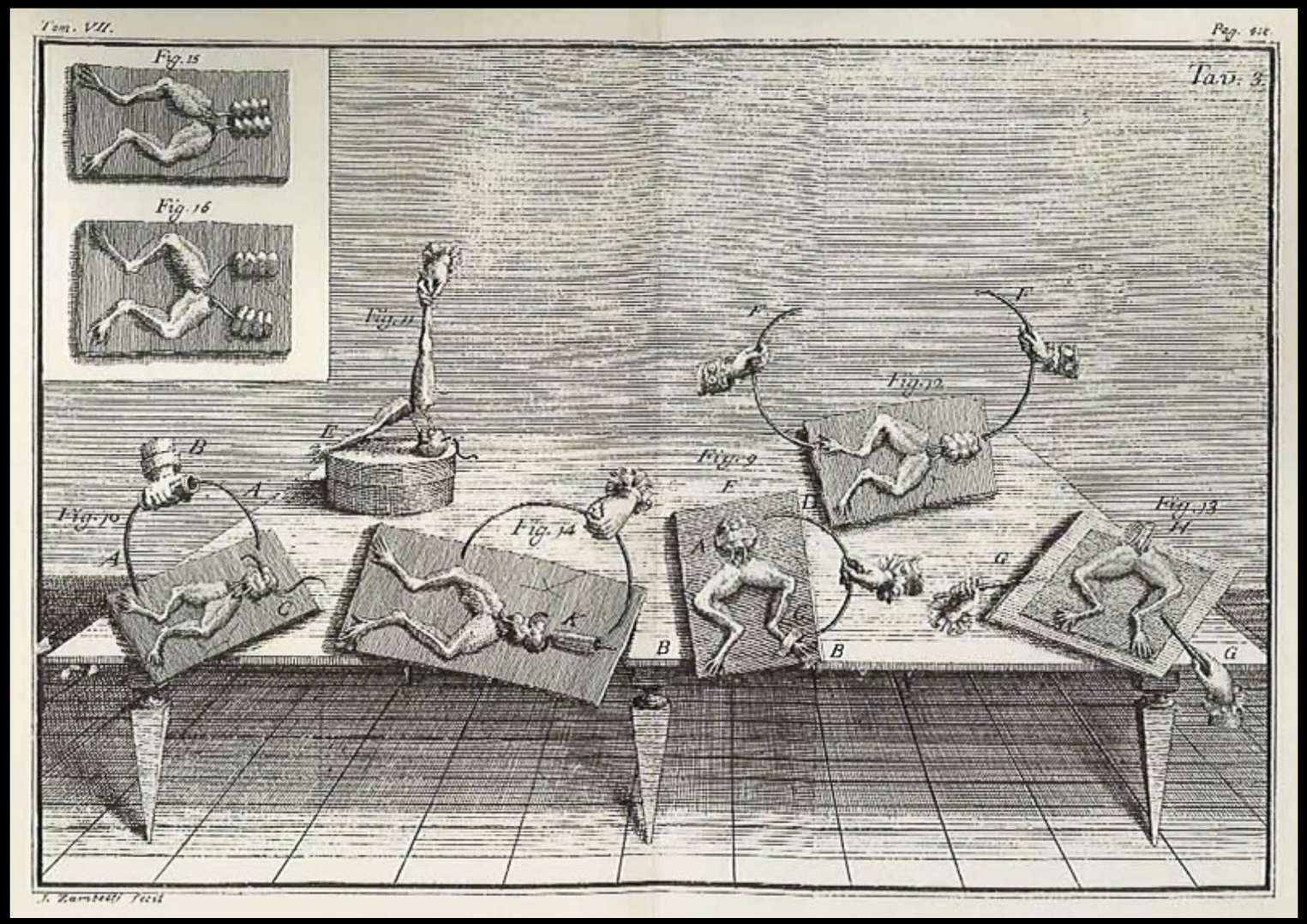
“I immediately repeated the experiment in different places with different metals and at different hours of the day.
The results were the same except that the contractions varied with the metals used; that is, they were more violent with some and weaker with others.”



Frogs and “animal electricity”

Galvani tries a more controlled experiment:

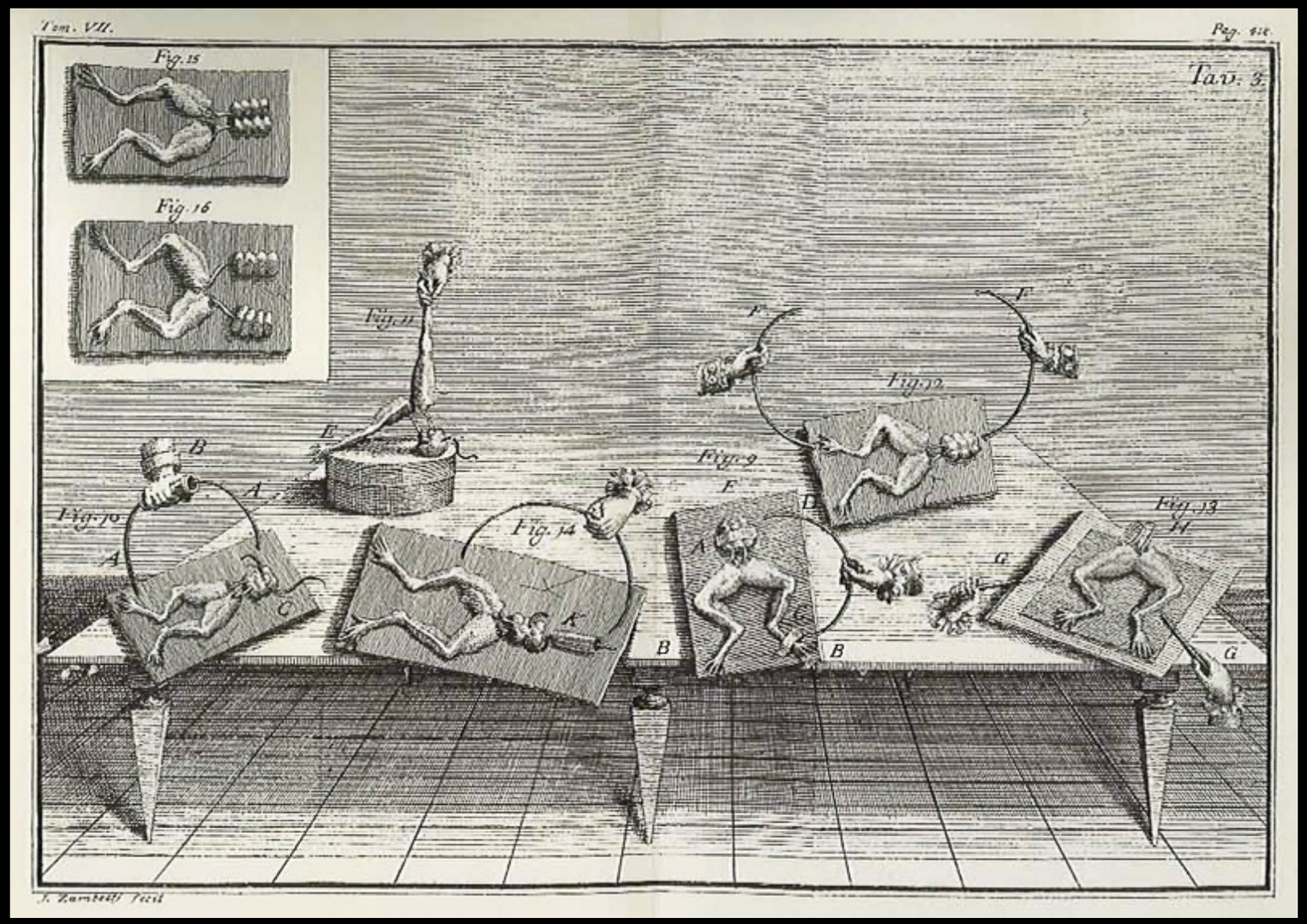
“It occurred to me to experiment with other substances that were either non-conductors or very poor conductors of electricity, like glass, gum, resin, and stones.



Frogs and “animal electricity”

Galvani tries a more controlled experiment:

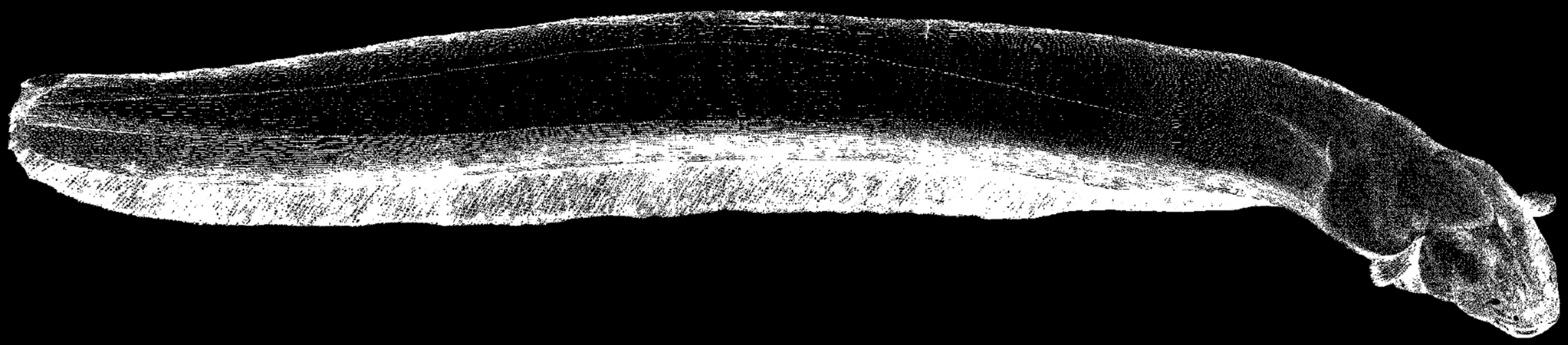
“It occurred to me to experiment with other substances that were either non-conductors or very poor conductors of electricity, like glass, gum, resin, and stones. No muscular contractions or movements were evident.”



Frogs and “animal electricity”

His conclusions:

“Gymnotus Electricus”: electric eel

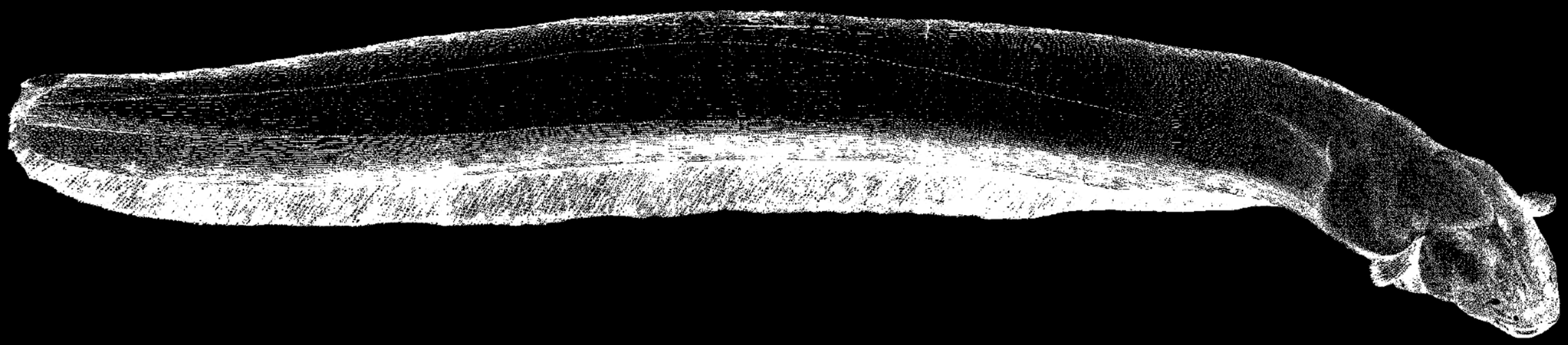


Frogs and “animal electricity”

His conclusions:

“These results surprised us greatly and led us to suspect that the electricity was inherent in the animal itself.”

“Gymnotus Electricus”: electric eel



Frogs and “animal electricity”

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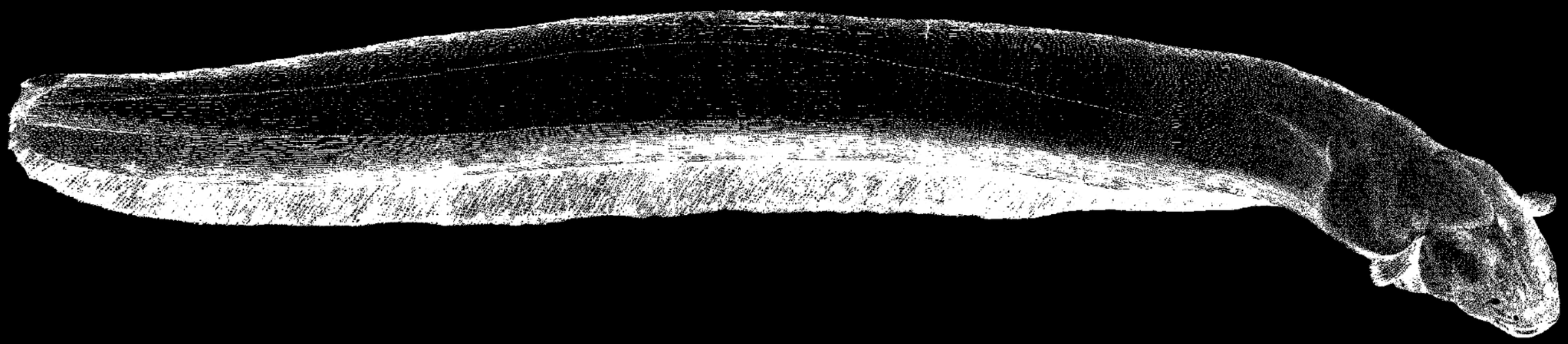
“An observation that a kind of circuit of a delicate nerve fluid is made from the nerves to the muscles when the phenomenon of the contractions is produced, similar to the electric circuit which is completed in a Leyden jar […]”

“Gymnotus Electricus”: electric eel



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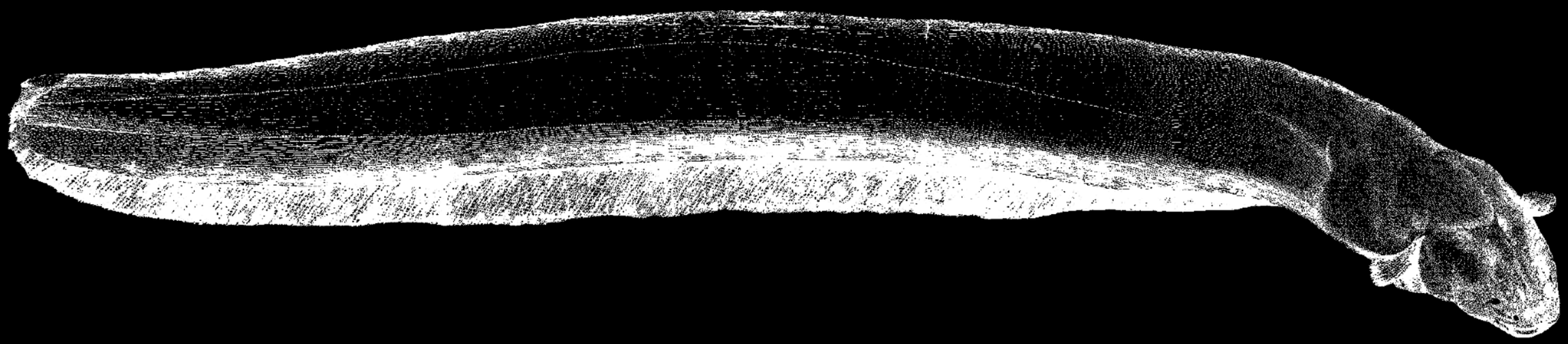
→ “Animal electricity”

“Gymnotus Electricus”: electric eel



Frogs and “animal electricity”

His conclusions:

“These results surprised us greatly and led us to suspect that the electricity was inherent in the animal itself.”

“An observation that a kind of circuit of a delicate nerve fluid is made from the nerves to the muscles when the phenomenon of the contractions is produced, similar to the electric circuit which is completed in a Leyden jar […]”

→ **“Animal electricity”**

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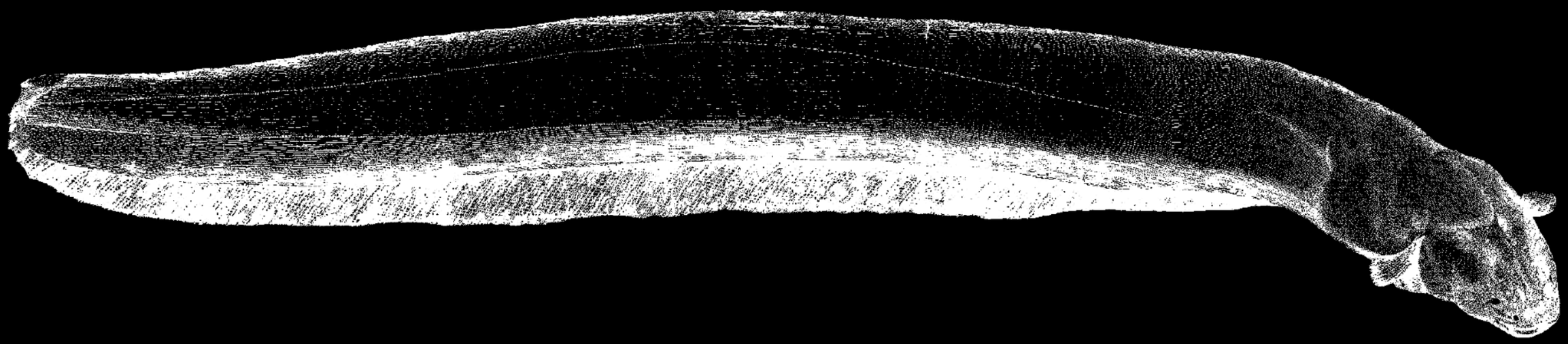
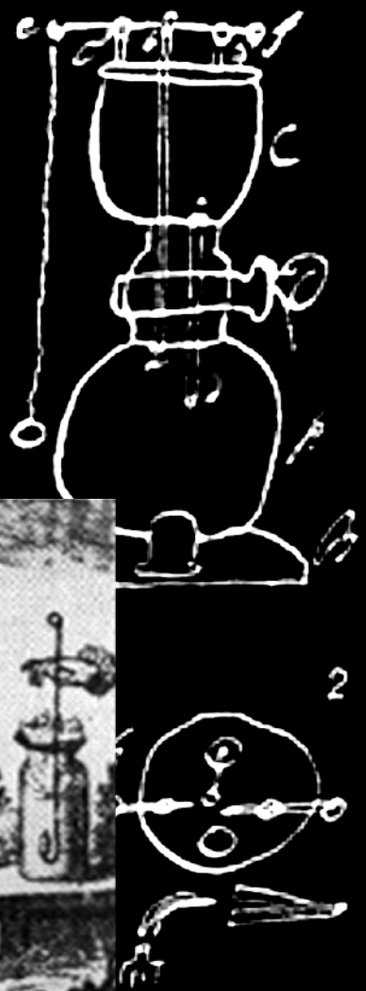


But: *“contractions varied with the metals used”*

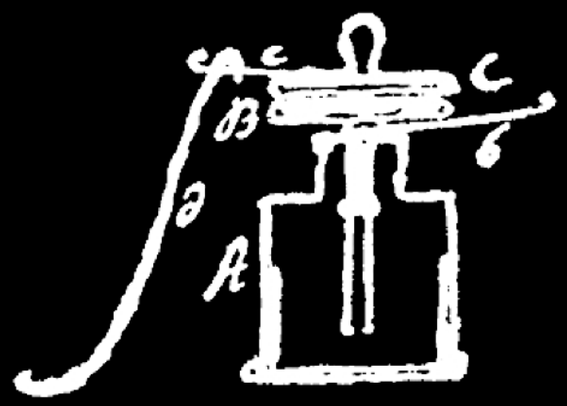
Alessandro Volta

Physicist, chemist, university lecturer

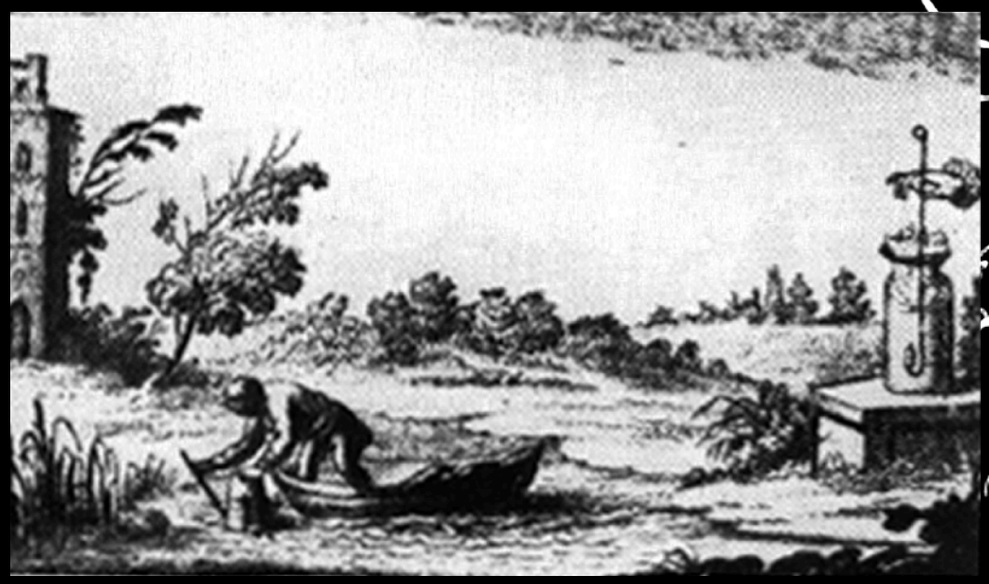
Doctoral thesis:
“On the Attractive Force of the Electric Fire,
and on the Phenomena Dependent On It”



“Condenser electrometer”



Collecting methane
in the marshes



"What can be done that’s any good if things can’t be reduced to degrees and measurements - specially in Physics?”

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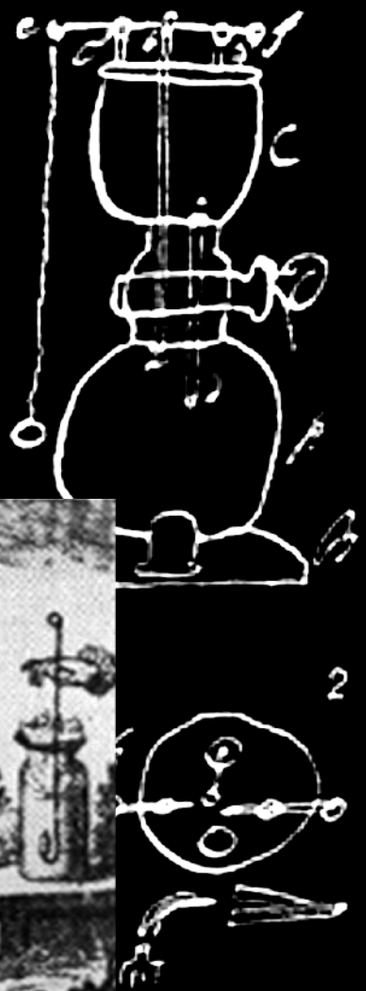

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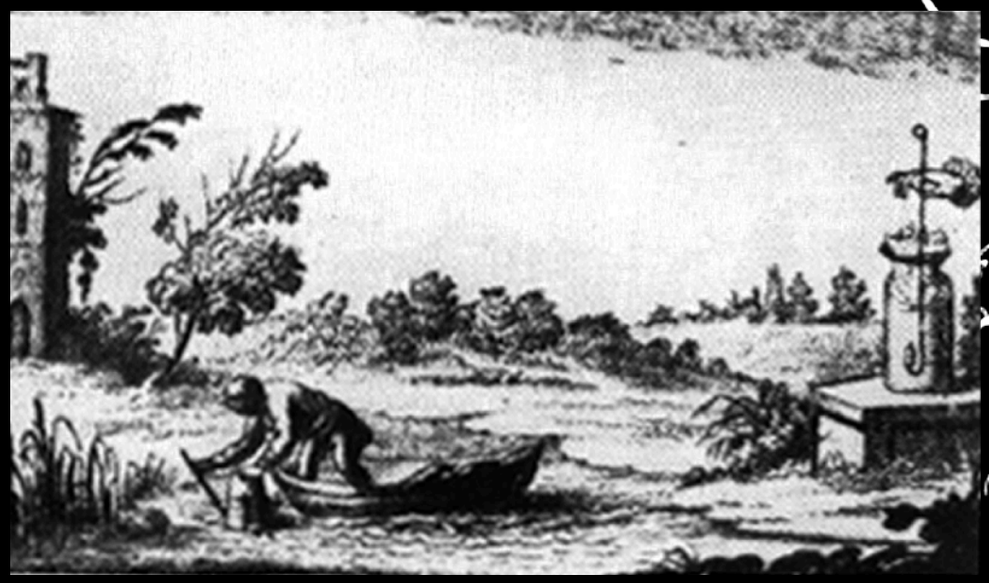

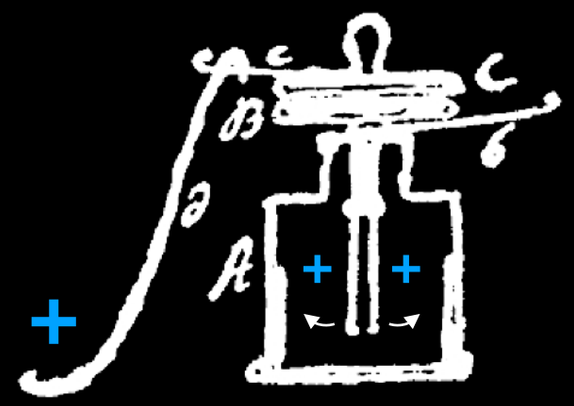

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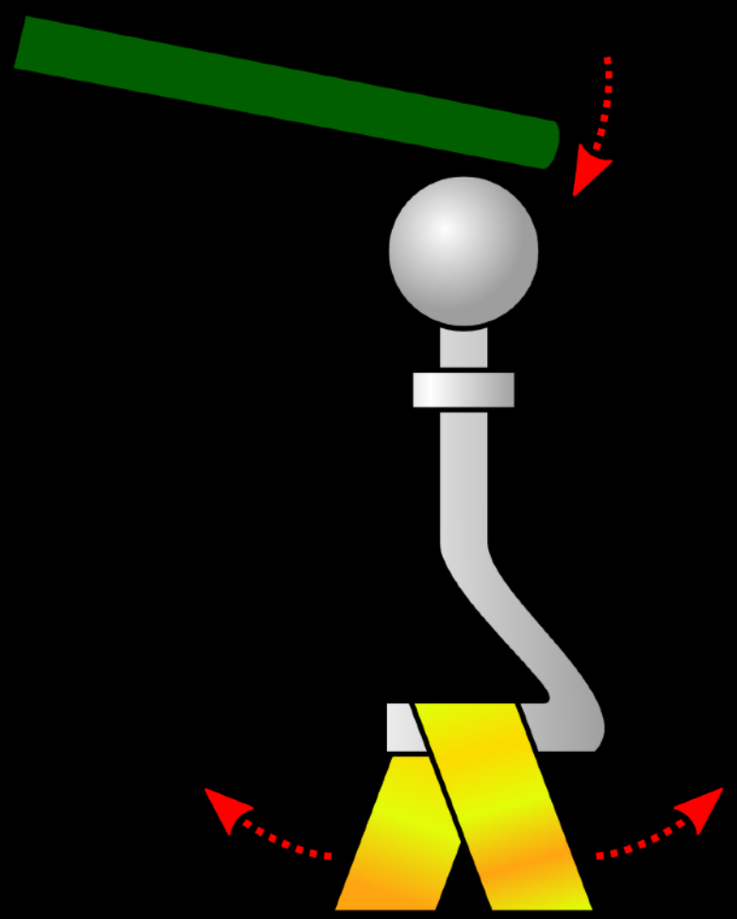

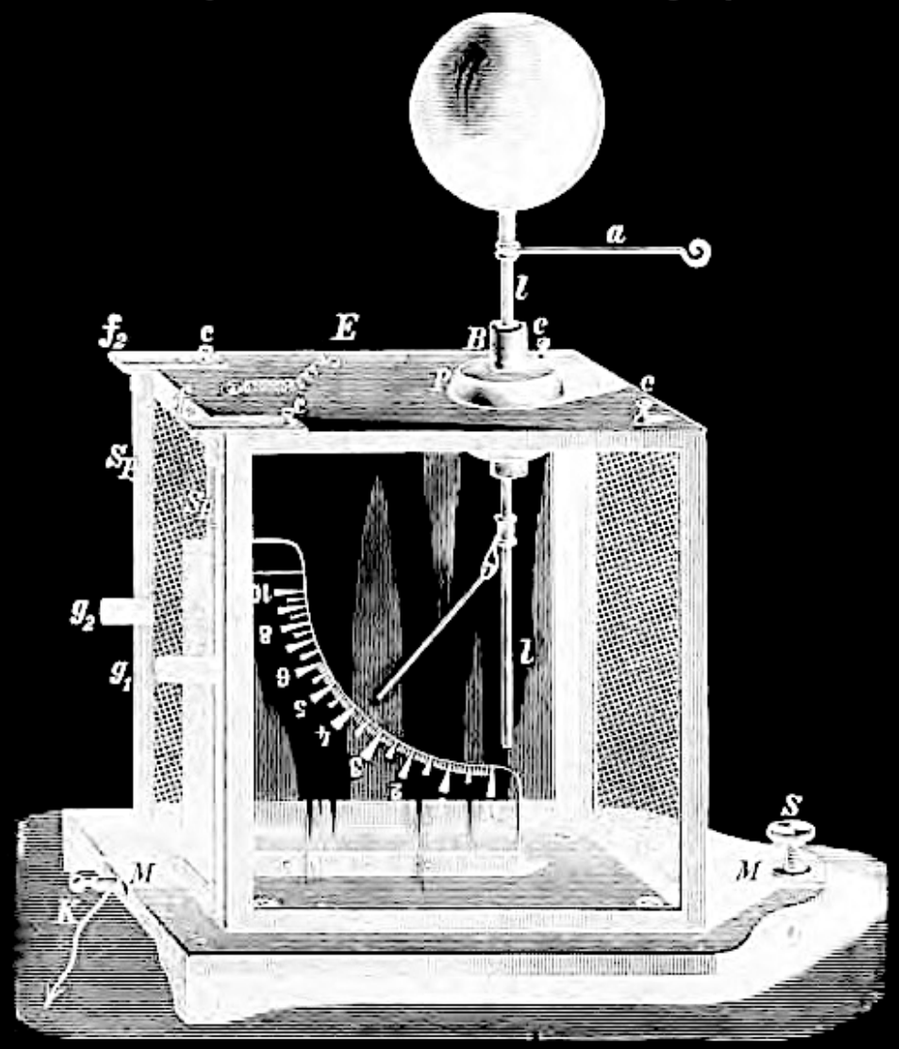

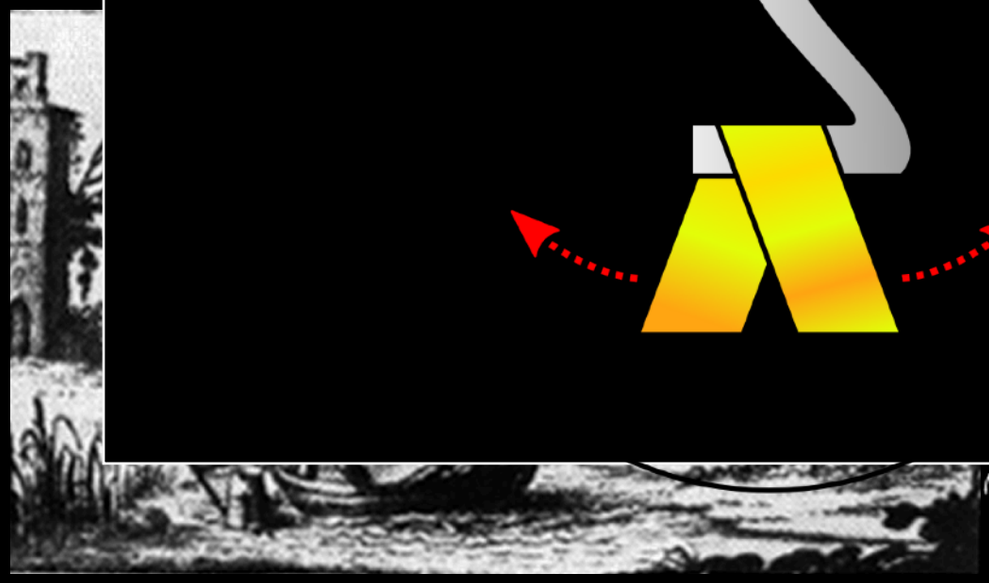

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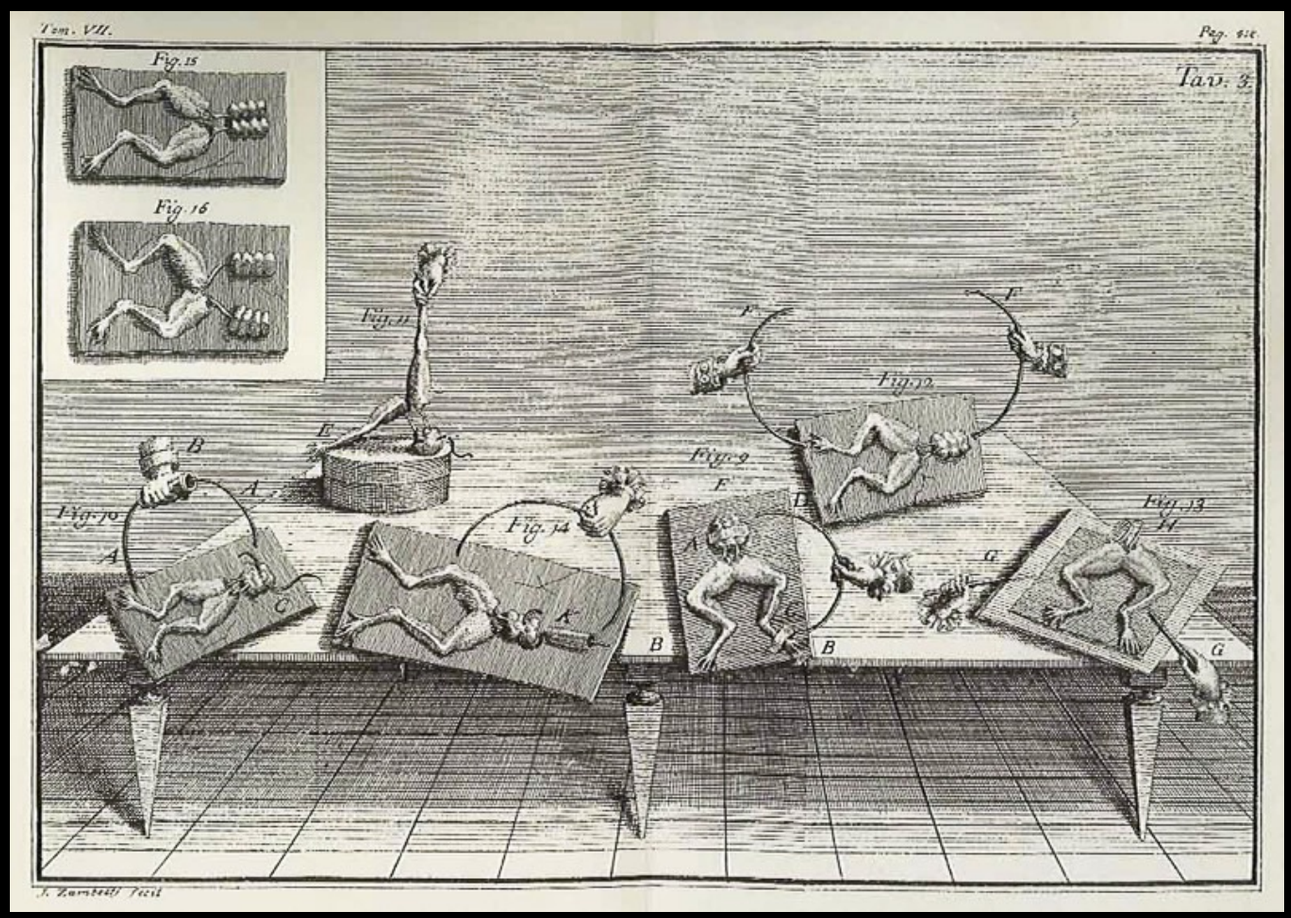
Volta’s opposition

In a letter, May 1793:



Galvani’s frogs merely supply some “wet substance”!

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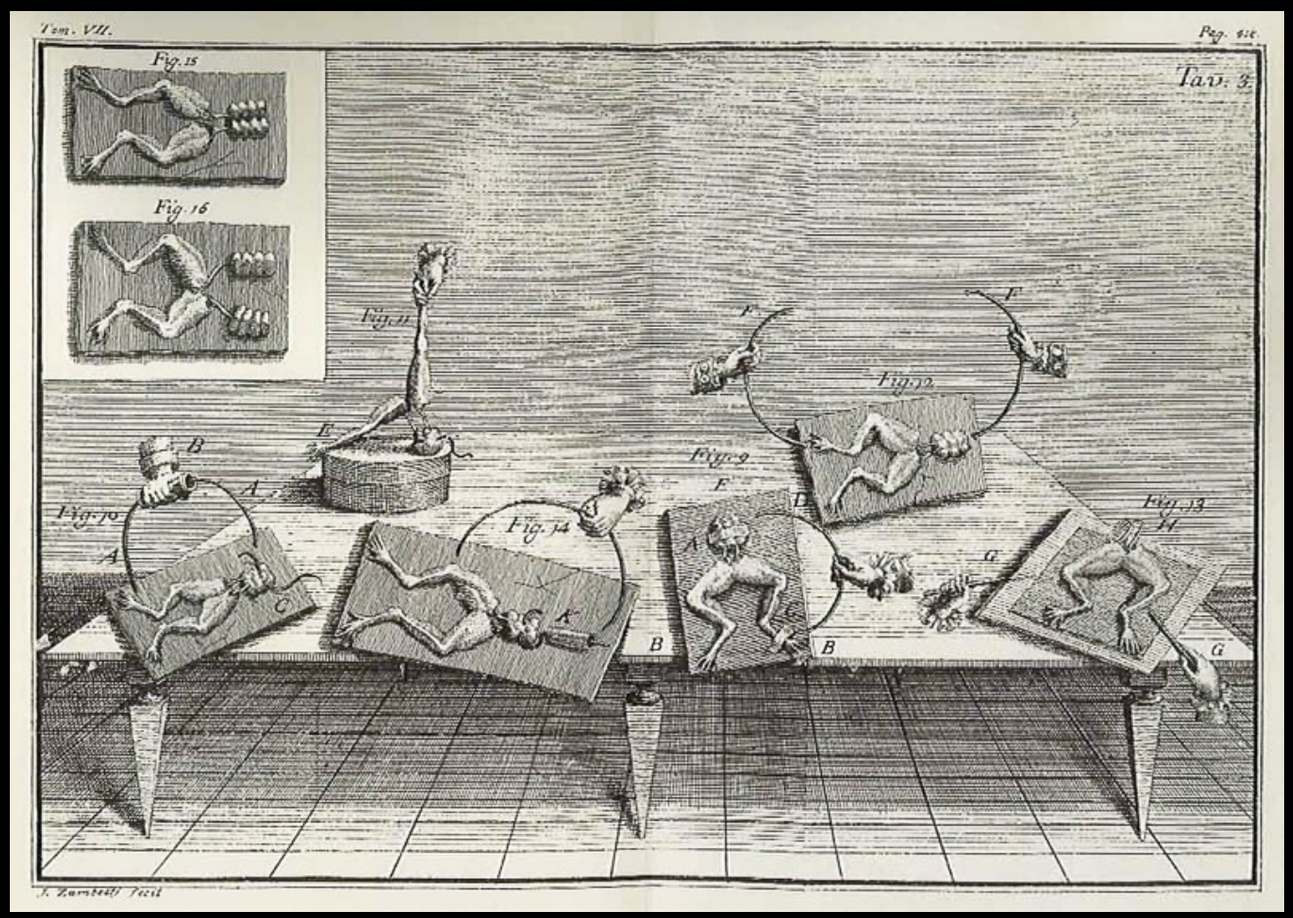

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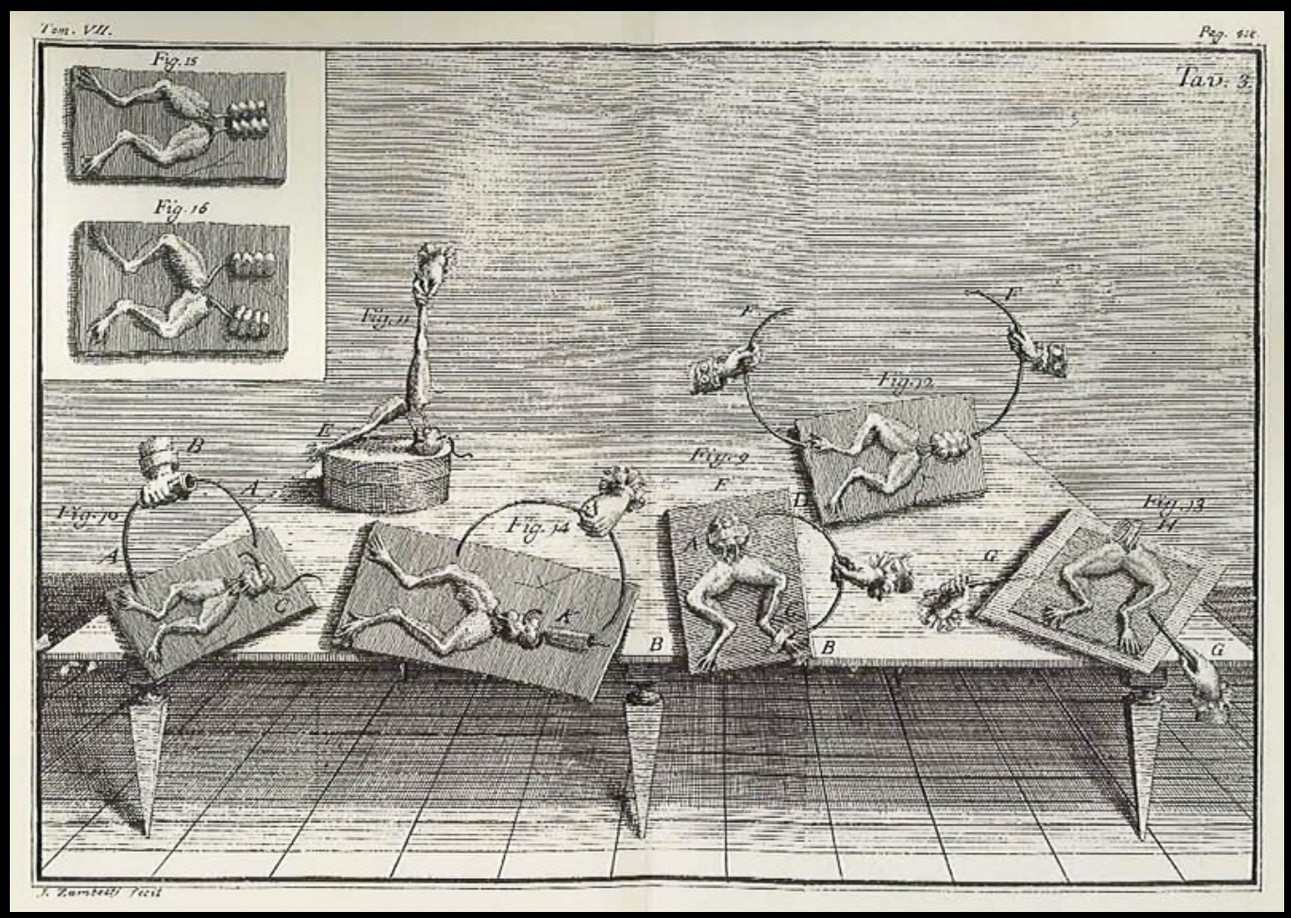
In a letter, May 1793:

“The name of animal electricity is by no means proper, in the sense intended by Galvani […]”

“No, this is mere artificial electricity induced by an external cause, that is, excited originally in a manner hitherto unknown, by the connexion of metals with any kind of wet substance.”



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In a letter to the Royal Society, March 1800:

"The apparatus to which I allude, and which will, no doubt, astonish you, is only the assemblage of a good number of good conductors of different kinds arranged in a certain manner."

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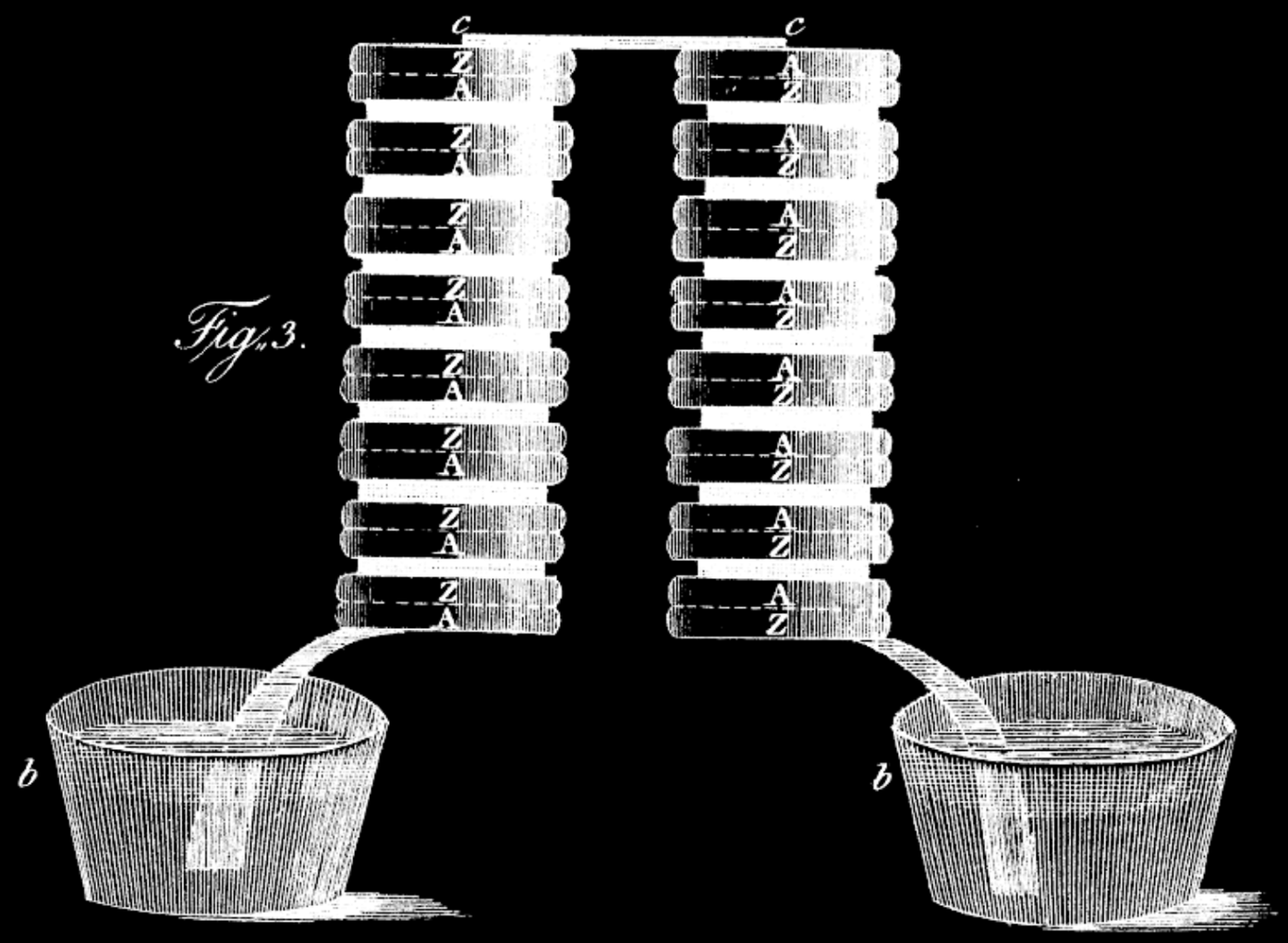
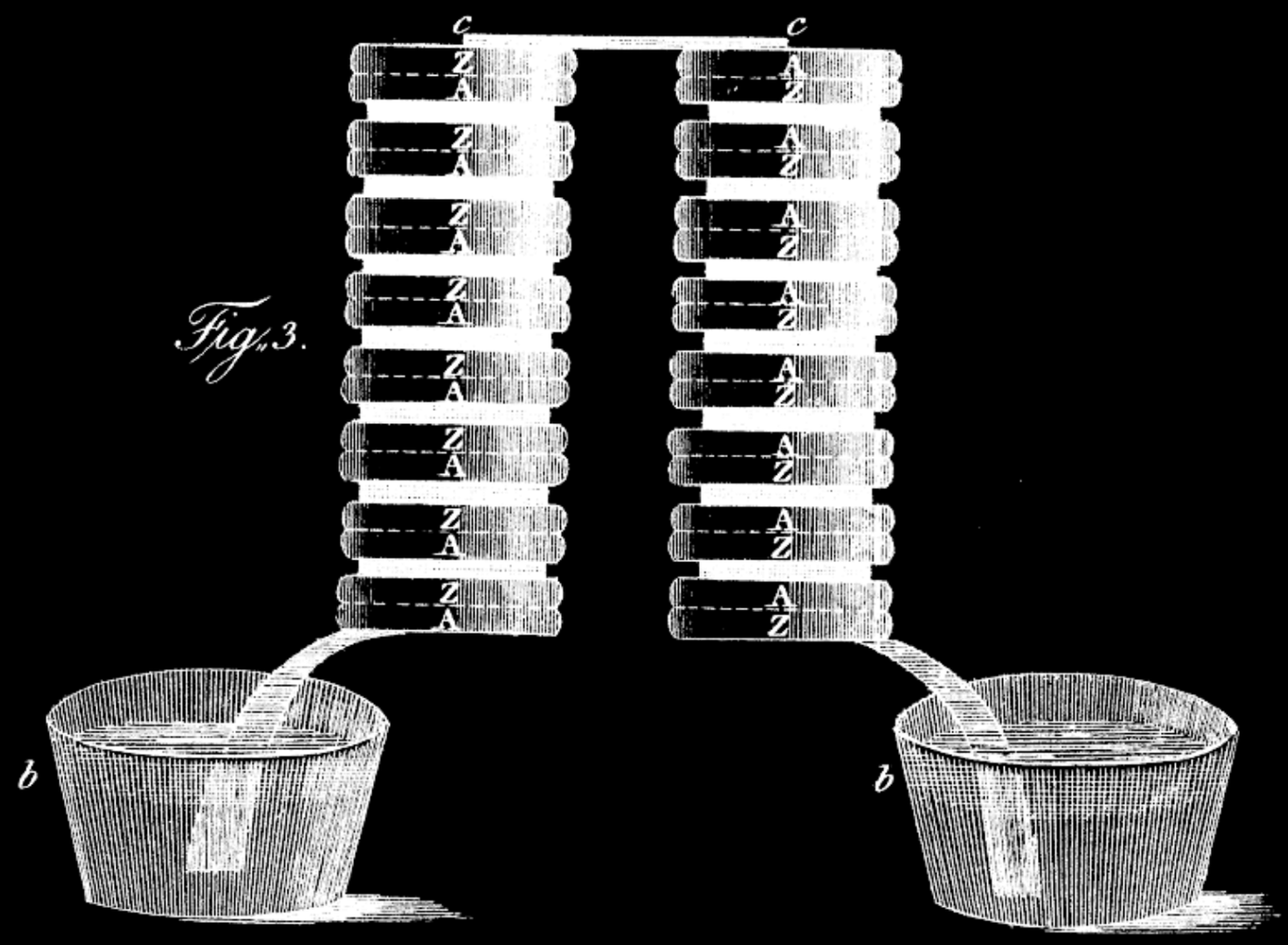


Fig. 3.

Volta's "artificial electric organ"

In a letter to the Royal Society, March 1800:

"Thirty, forty, sixty or more pieces of copper, applied each to a piece of zinc,
and as many pieces of pasteboard, well soaked in water;
such strata interposed between every pair of two different metals in an alternate series."



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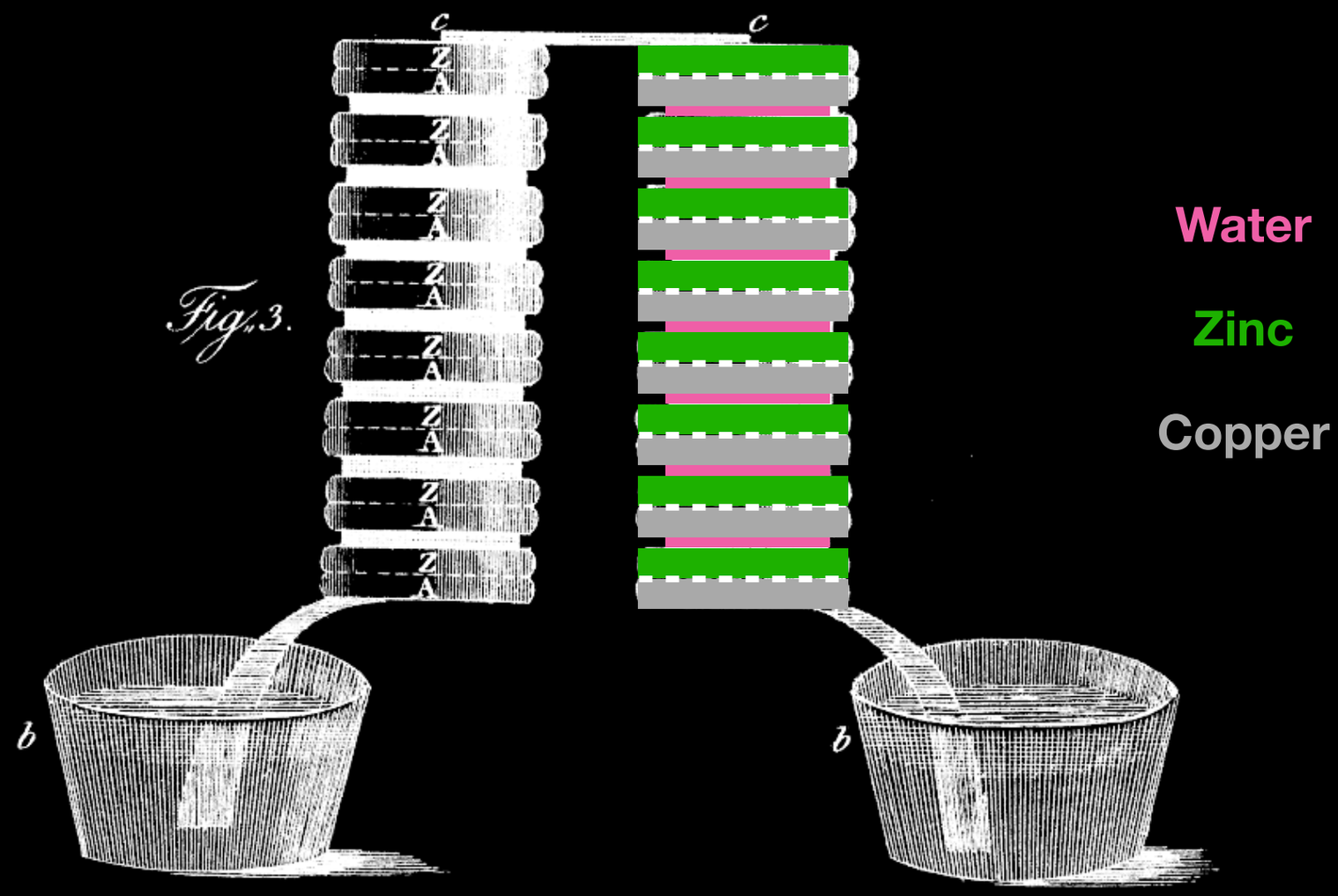


Fig. 3.

Water

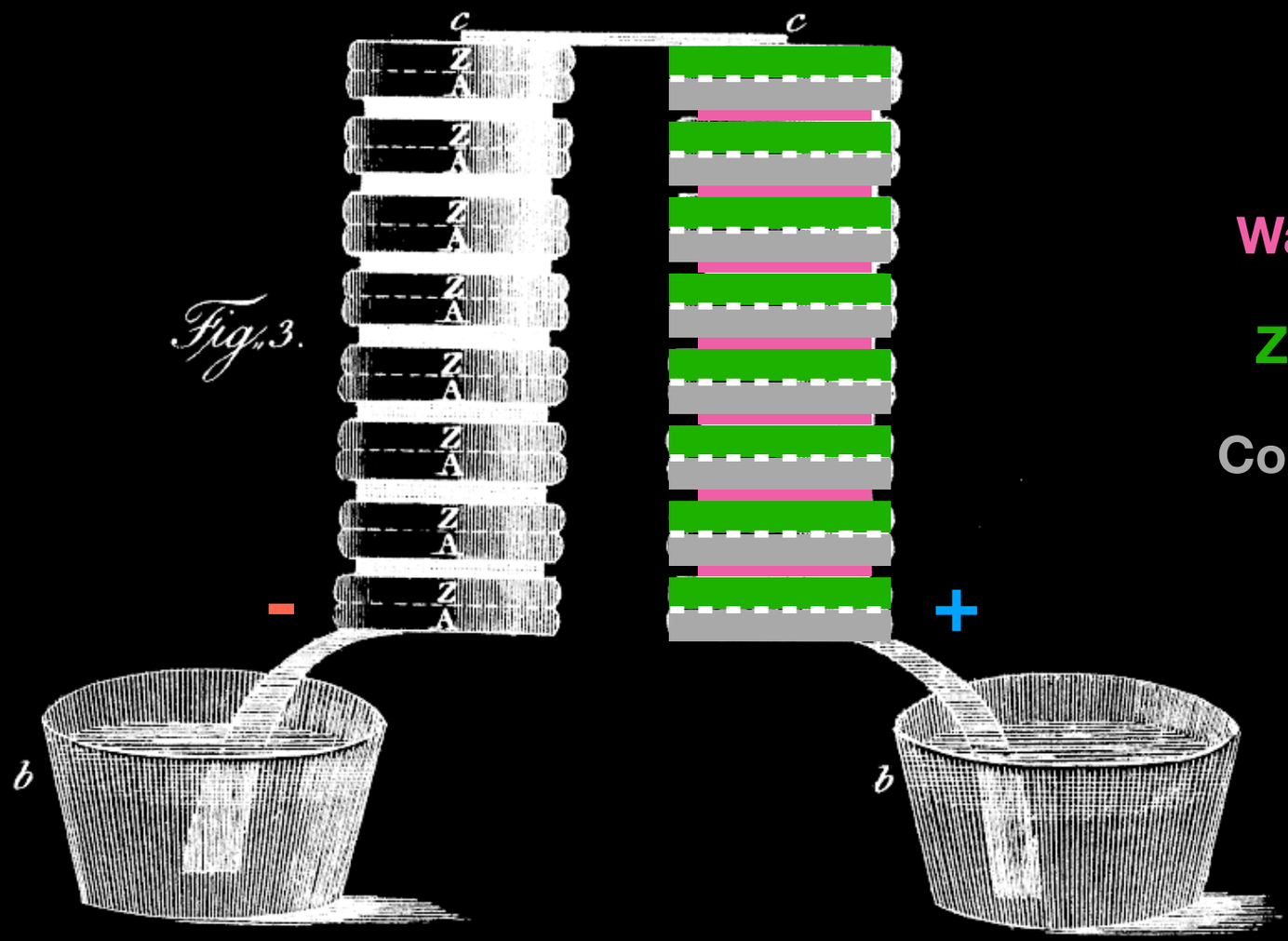
Zinc

Copper

Volta's "artificial electric organ"

In a letter to the Royal Society, March 1800:

"This is all that is necessary for constituting my new instrument, which, as I have said, imitates the effects of the Leyden flasks."



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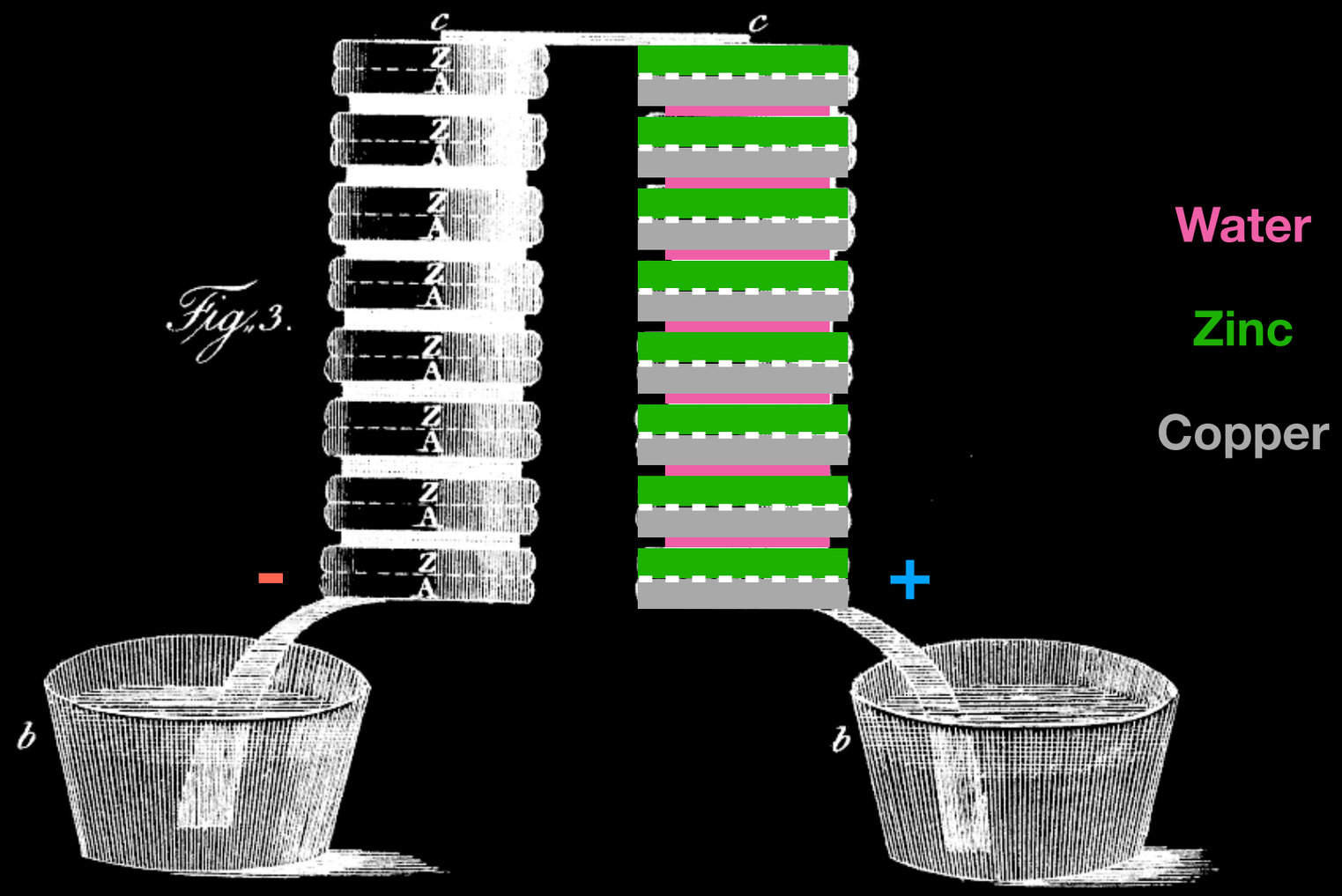

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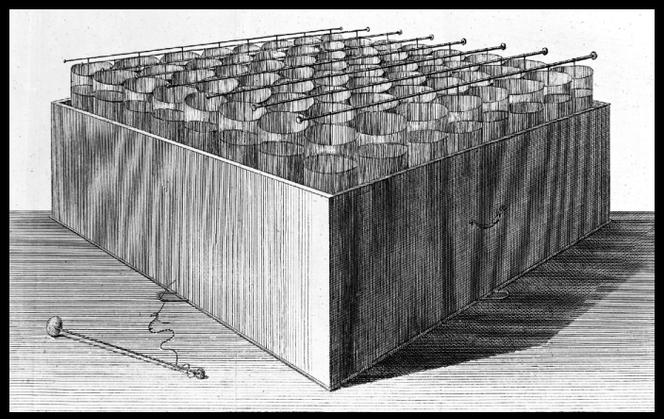
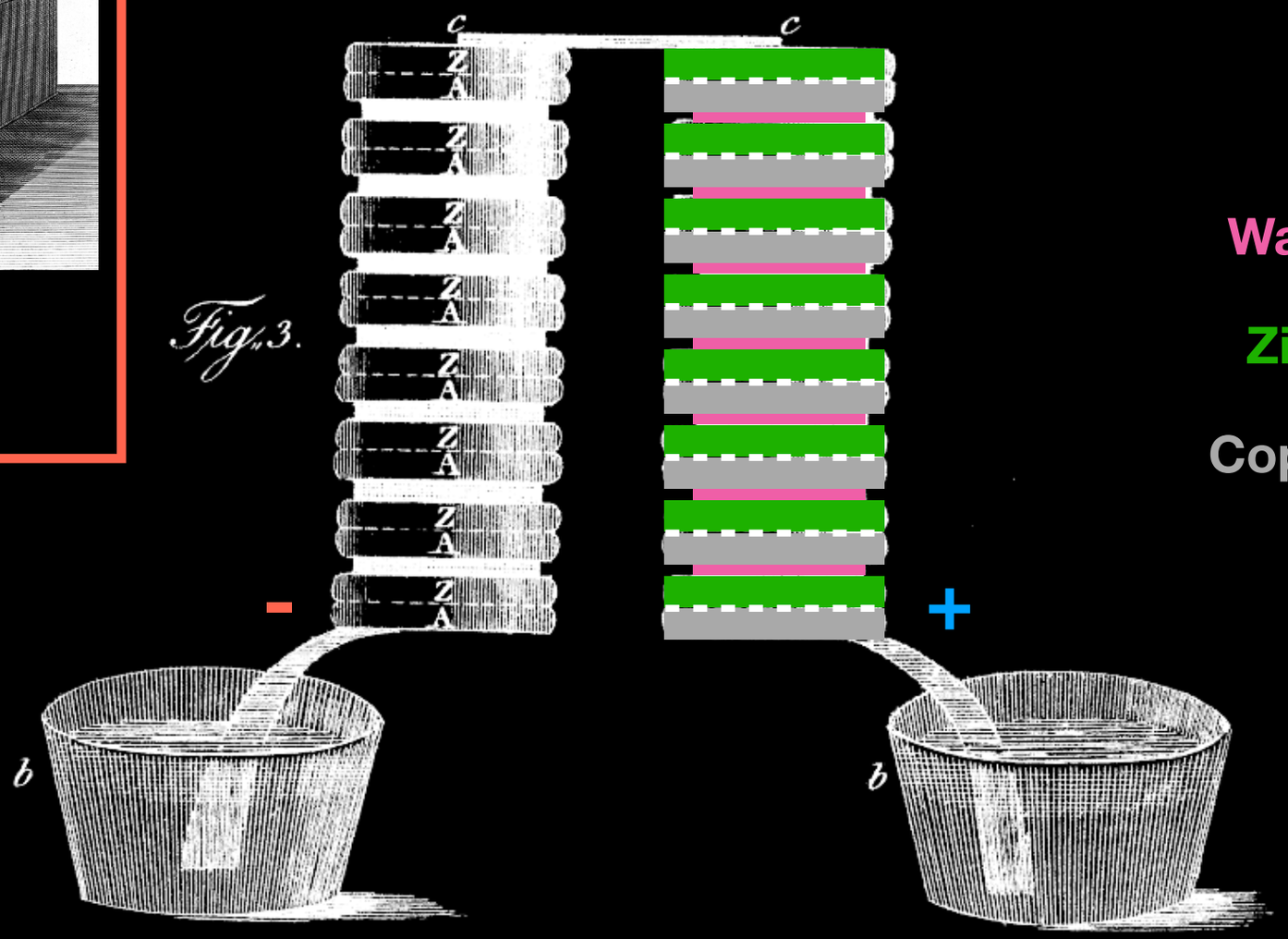


"Battery" of Leyden Jars



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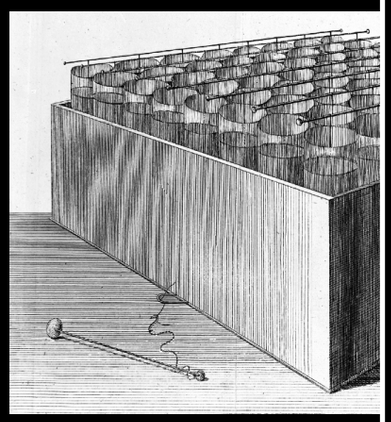
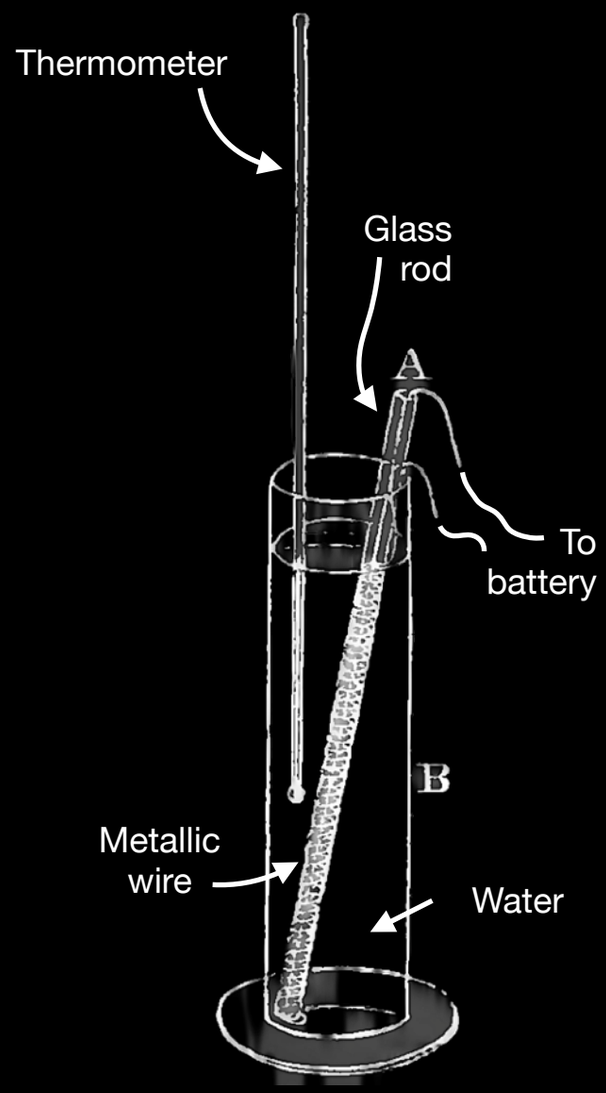
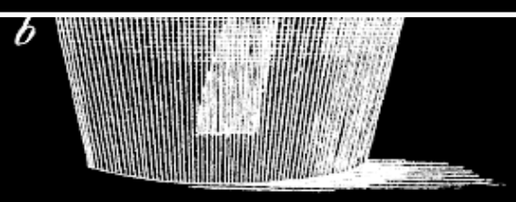


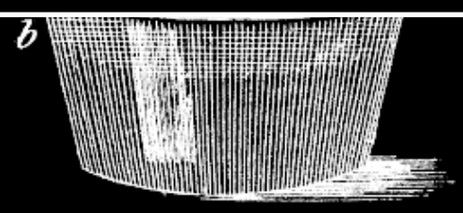
"Battery
Leyden

James Joule (ca. 1840):

[…] when a current of voltaic electricity is propagated along a metallic conductor […]







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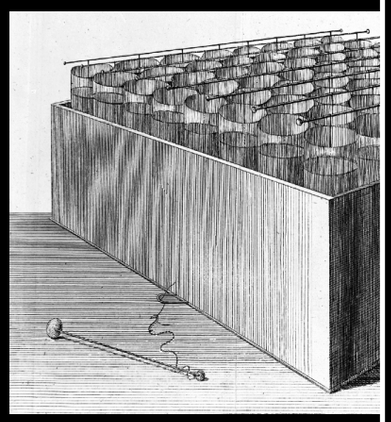

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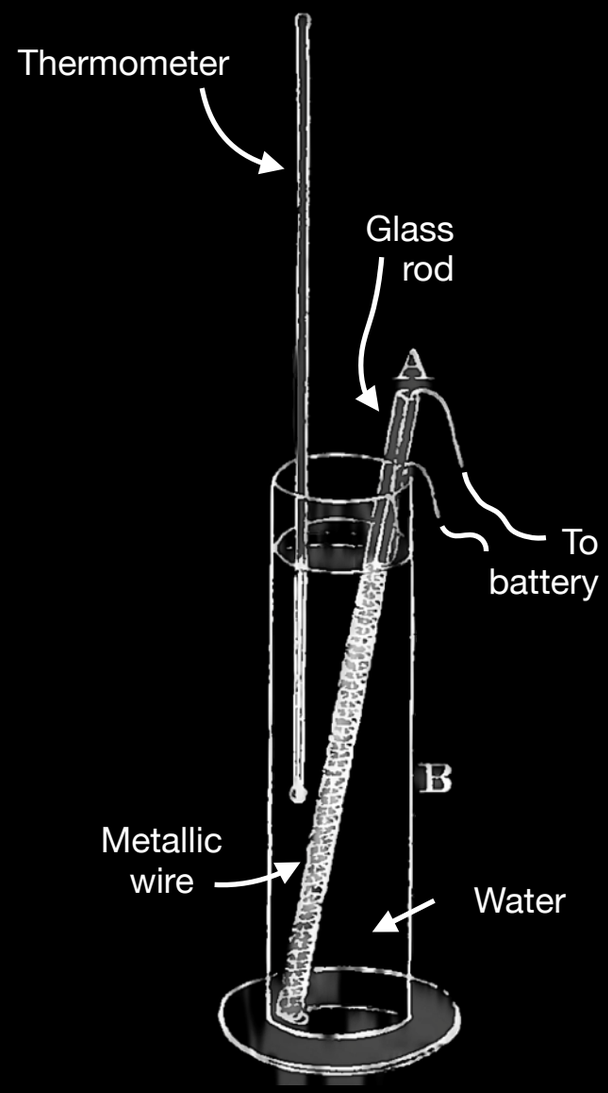
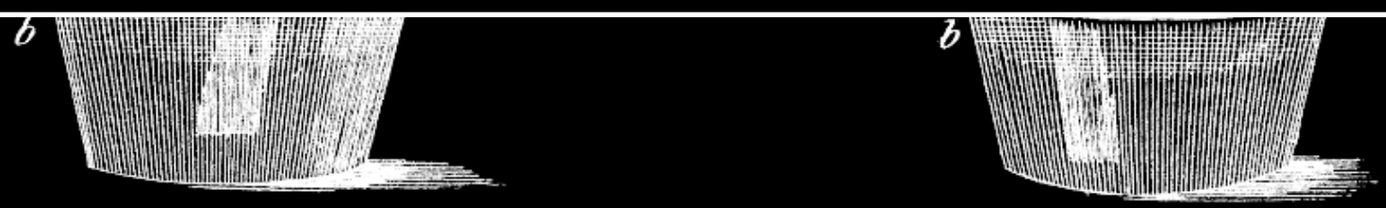
The first "steady-state" source of electricity!





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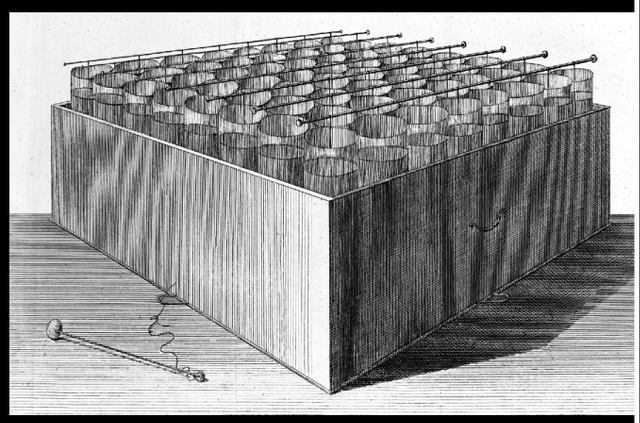

"Battery" of Leyden Jars

Still a very convenient source of electricity!

(My) references

1. J. L. Heilbron, *“Electricity in the 17th and 18th Centuries”*, University of California Press (1979)
2. W. Gilbert, *“De Magnete, Magneticisque Corporibus, et de Magno Magnete Tellure”* (1628)
3. A. Assis, “The Experimental and Historical Foundations of Electricity”, C. Roy Keys Inc. (2010)
4. M. Faraday, “Experimental Researches in Electricity”
5. B. Jones, “The Life and Letters of Faraday”, Longmans, Green, And Co (1870)
6. A. Mauro, “The Role of the Voltaic Pile in the Galvani-Volta Controversy Concerning Animal vs Metallic Electricity”, Journal of the History of Medicine (1969)
7. F. Hauksbee, “Physico-Mechanical Experiments”, R. Brugis (1709)
8. J. Henry, “Scientific Writings”, Smithsonian Institution (1886)
9. H. Hertz, “Electric Waves”, Macmillan and Co (1893)
10. O. E. Dunlap Jr., “Marconi: The Man and his Wireless”, Macmillan (1937)
11. D. B. Malament, Ed. “Reading Natural Philosophy: Essays in the History and Philosophy of Science and Mathematics”, Open Court (2002)
12. R. De Andrade Martins, “Resistance to the Discovery of Electromagnetism: Ørsted and the Symmetry of the Magnetic Field”, In: “Volta and the history of electricity” (2003)
13. B. Park, “A History of Electricity from Antiquity to the Days of Benjamin Franklin”, John Wiley & Sons (1898)
14. Brother Arnold, “The Letter of Petrus Peregrinus on the Magnet”, McGraw-Hill (1904)
15. J. Priestley, “The History and Present State of Electricity”, Bathurst & Lowndes (1775)
16. J. F. Keithley, “The Story of Electrical and Magnetic Measurements: From 500 BC to the 1940s”, Wiley-IEEE Press (1999)