

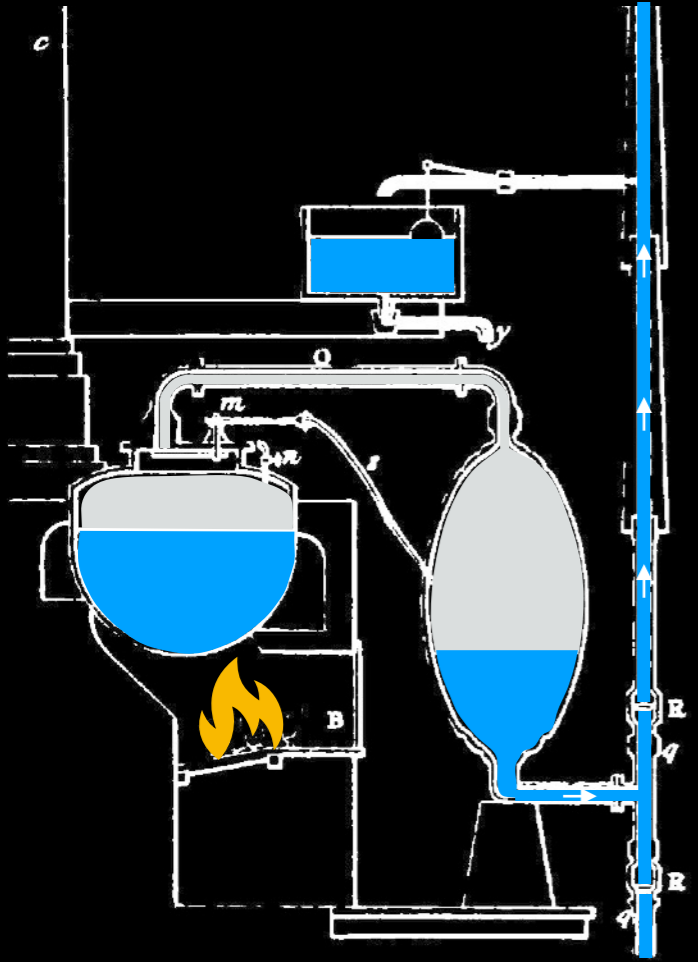


HOW FUNDAMENTAL SCIENCE HAS CHANGED THE WORLD

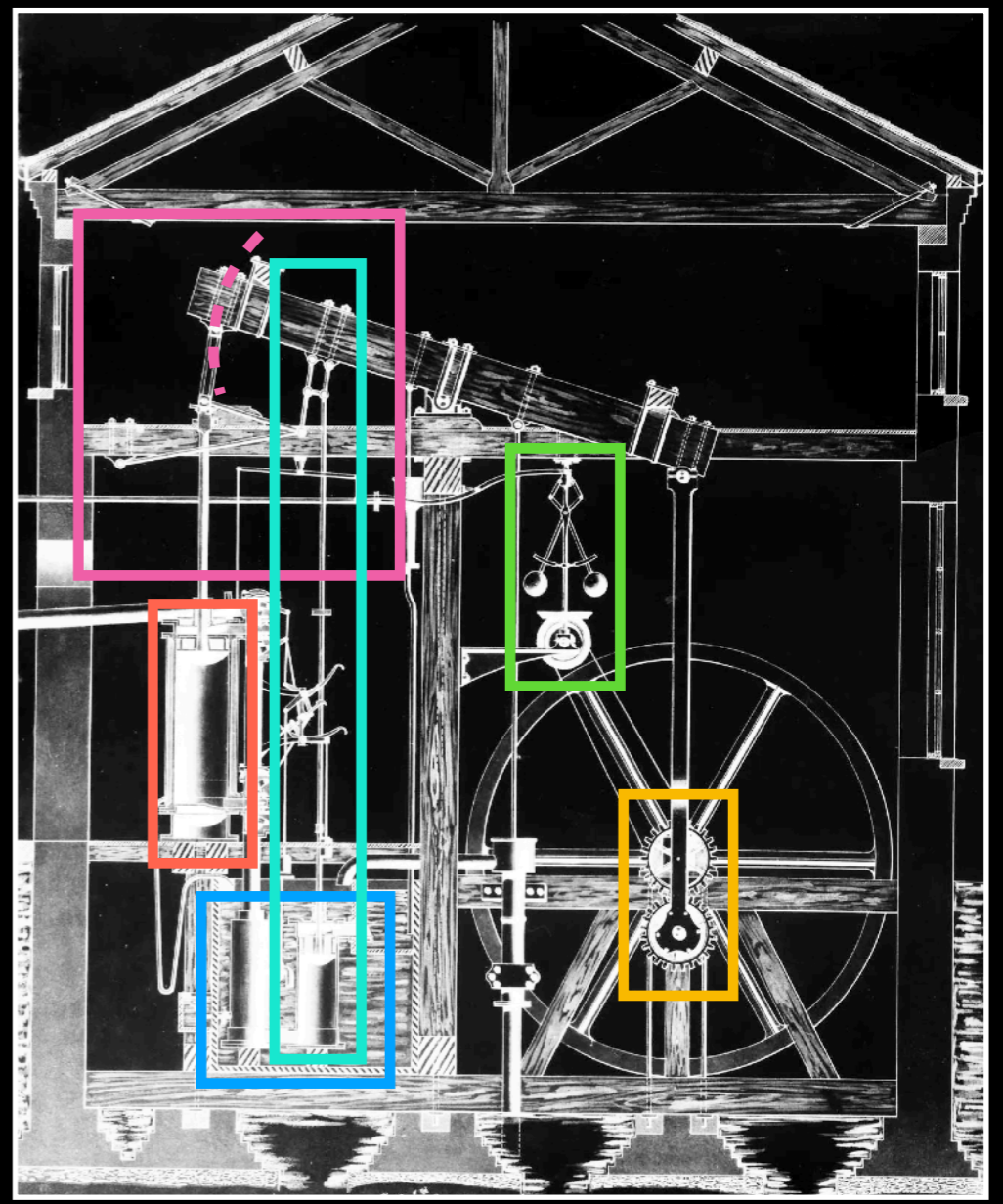
A STORY OF INVENTION AND DISCOVERY

Philipp Windischhofer
October 21, 2023

Captain Savery
(1698)



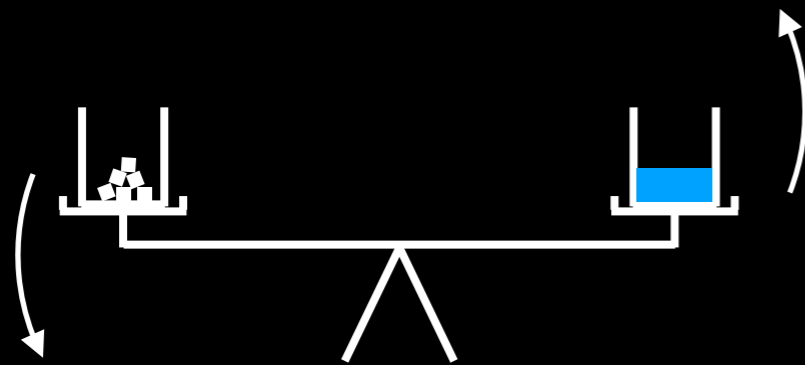
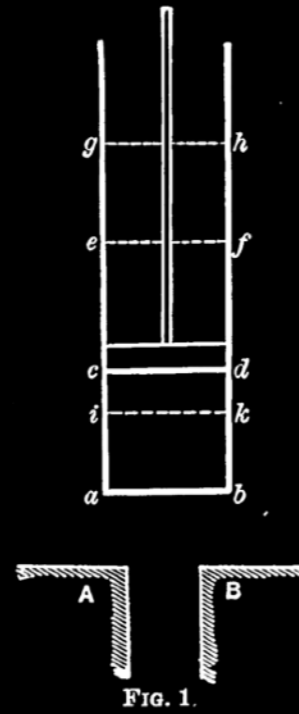
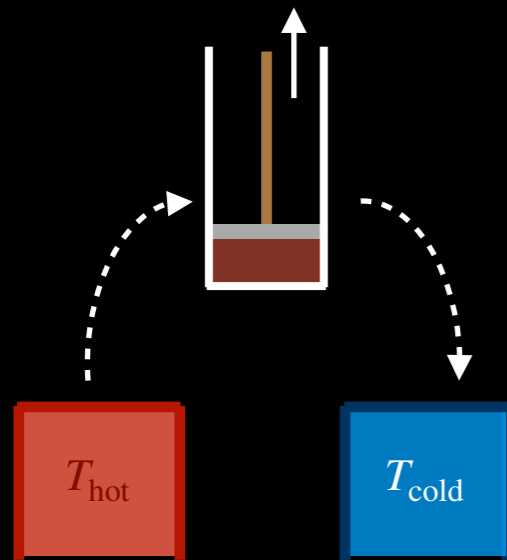
Thomas Newcomen
(1712)



James Watt (1769)

"Heat is an elastic fluid"

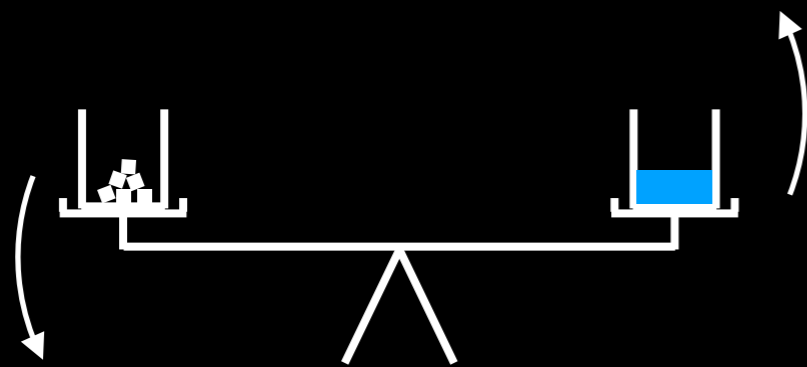
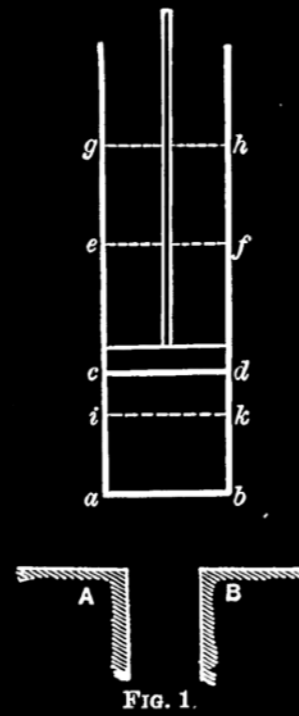
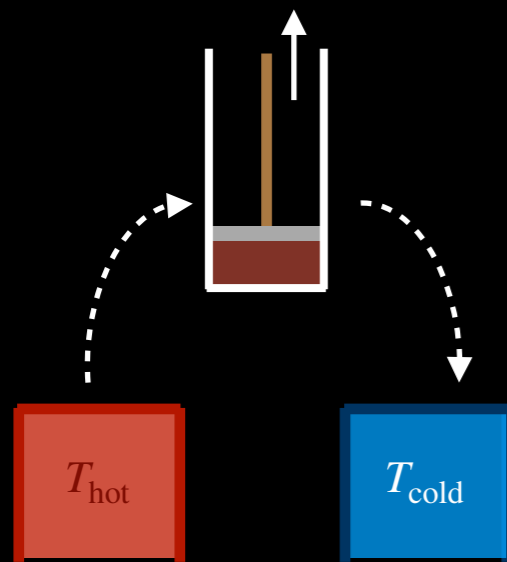
Sadi Carnot
(1824)



“Heat is an elastic fluid”

“Heat is the motion of particles”

**Sadi Carnot
(1824)**

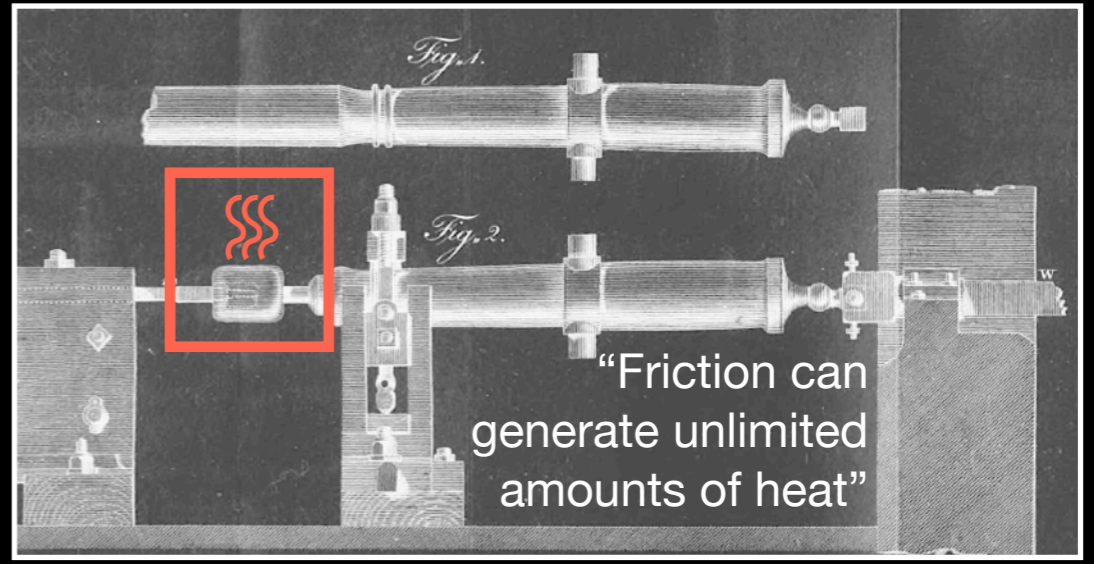
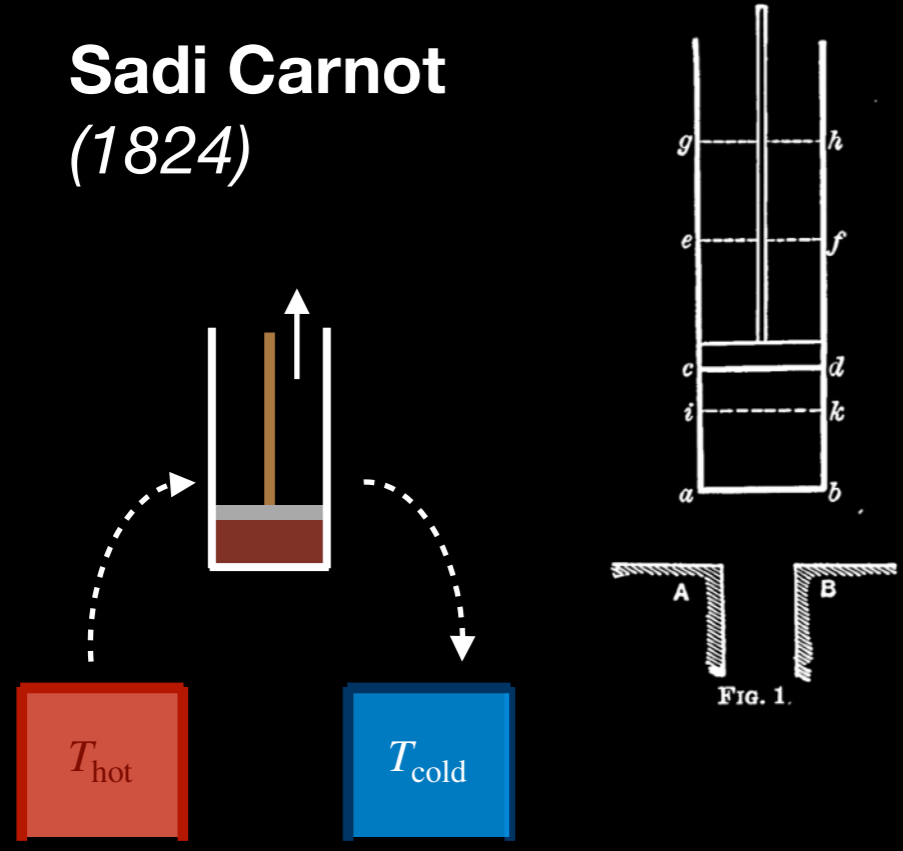


“Heat is an elastic fluid”

“Heat is the motion of particles”

Count Rumford (1798)

Sadi Carnot (1824)

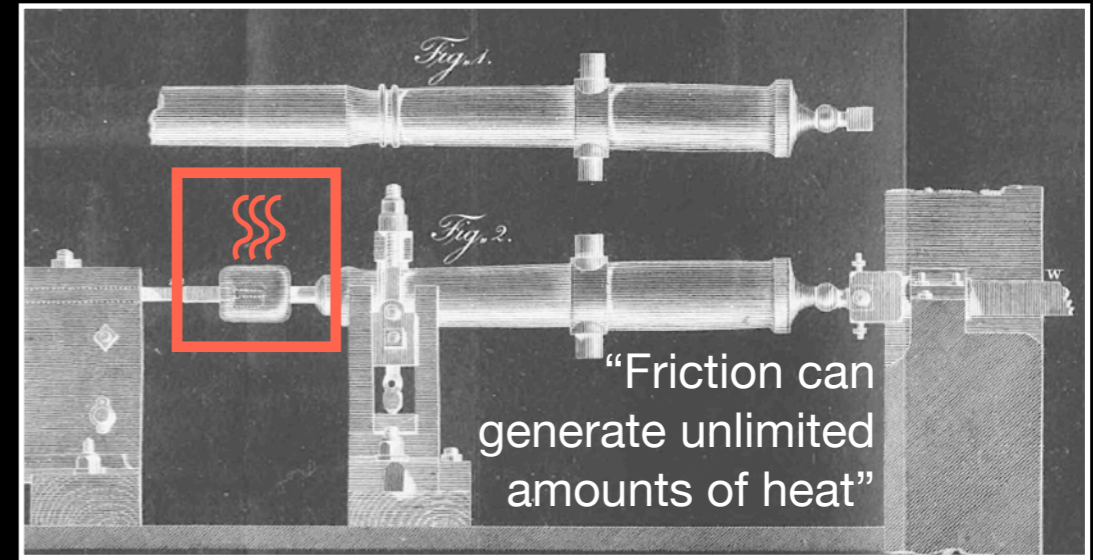
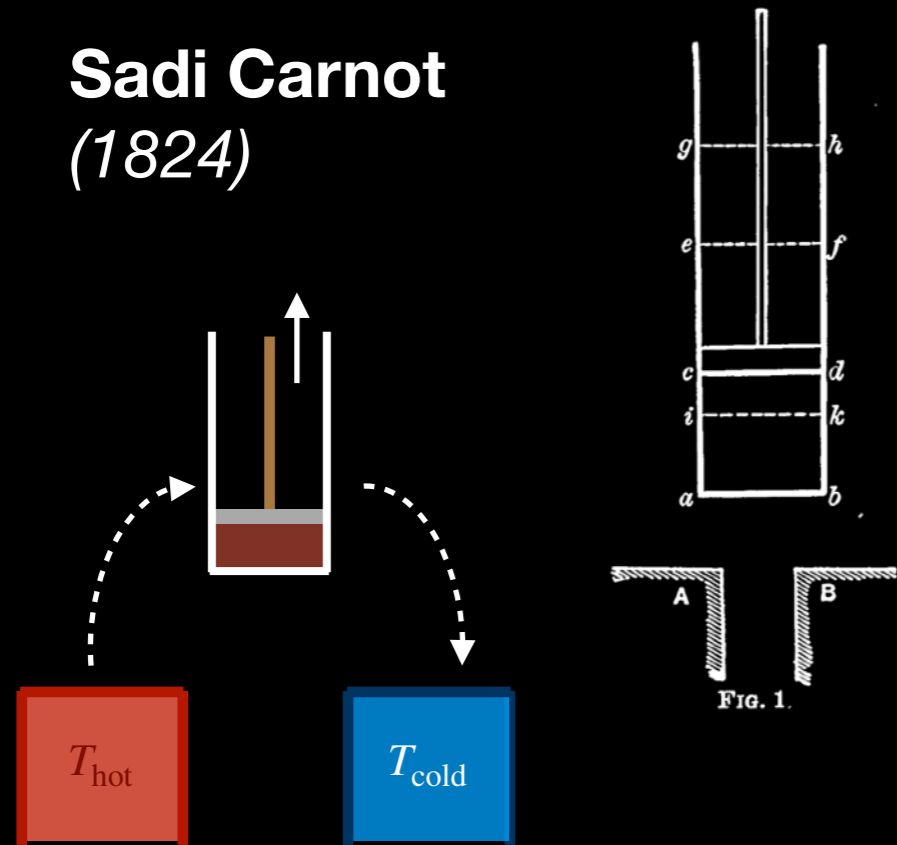


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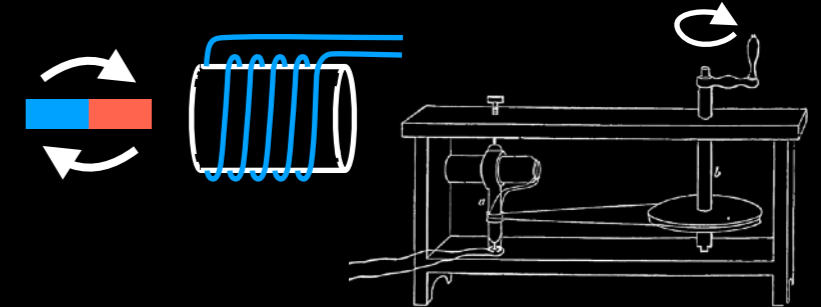
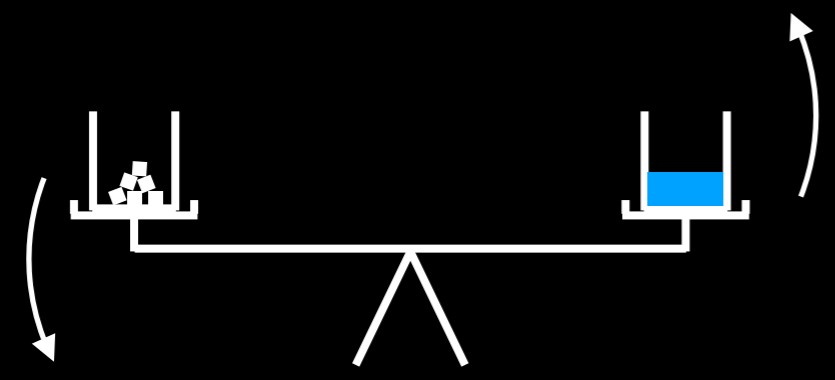
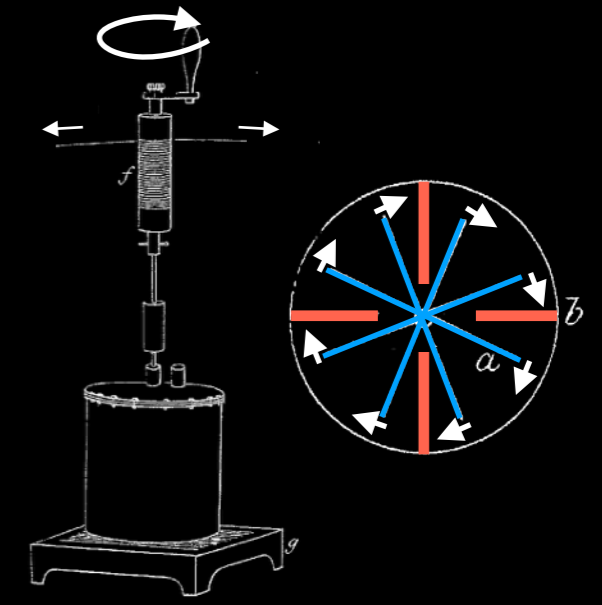
Count Rumford (1798)

Sadi Carnot (1824)



James Joule (1849)

“Mechanical energy generates a precise and universal amount of heat”



What is the
nature of electricity?

Back to ancient Greece (once again)



Plato

His “academy” near Athens

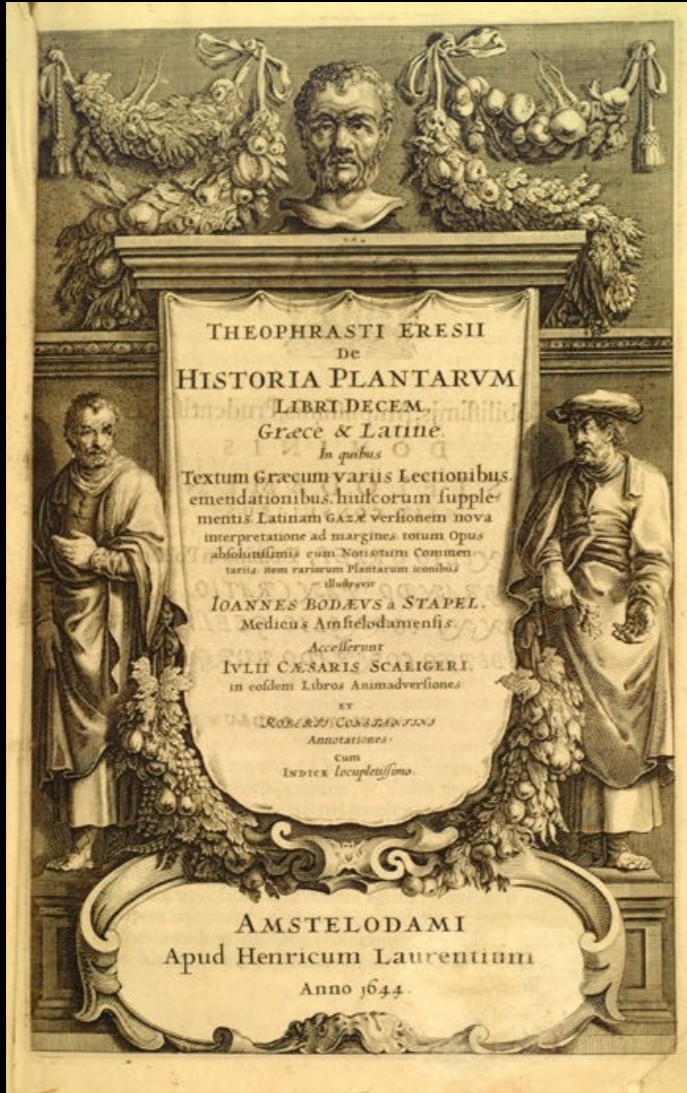


Life at the academy (ca. 350 BC)



Theophrastus (*Tyrtamus*)

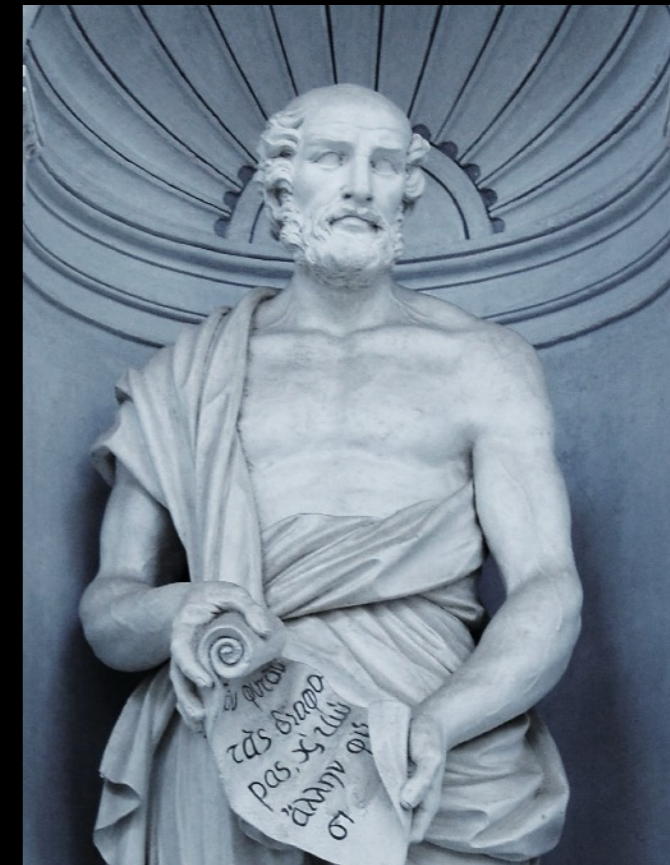
Botanist, physicist, mineralogist, psychologist



“Enquiry into plants”
“Father of botany”



“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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Amber: ἤλεκτρον (elektron)



“Static electricity”

“Triboelectricity”



Living with natural electricity and magnetism

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“The stone that attracts iron is the most remarkable and conspicuous example. This also is rare and occurs in few places. This stone too should be listed as having a similar power.”

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Living with natural electricity and magnetism

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It's the gods!

Plato (*Ion*, 380 BC):

“[Amber]
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Living with natural electricity and magnetism

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*"There is a divinity contained in the stone
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Living with natural electricity and magnetism

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Plato (*Ion*, 380 BC):

“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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Plato (*Ion*, 380 BC):

“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; 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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Plato (Ion, 380 BC):

“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; 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.”



“[Am
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Magnetism takes off

Lodestone compass (Han Dynasty, ~200 BC)

“South-pointing Fish”

First used for divinations, navigation by
11th century



Magnetism takes off

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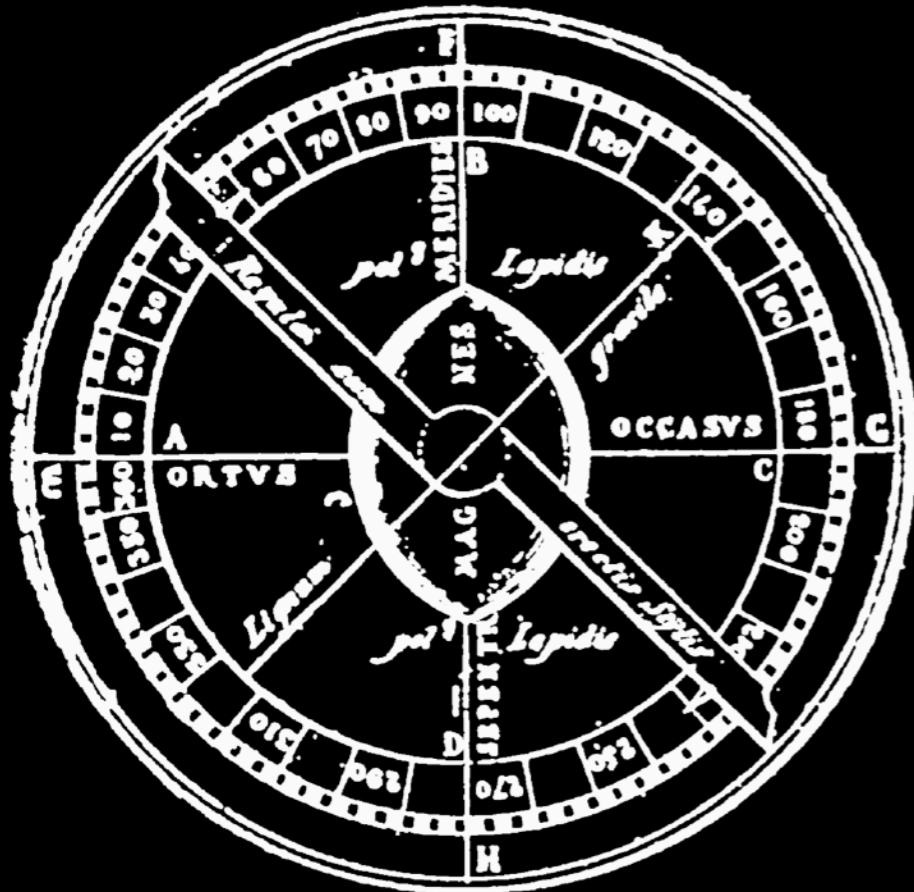


FIG. I.—AZIMUTH COMPASS

Pierre de Maricourt (1269)

Magnetism takes off

Lodestone compass (Han Dynasty, ~200 BC)

“South-pointing Fish”

First used for divinations, navigation by 11th century

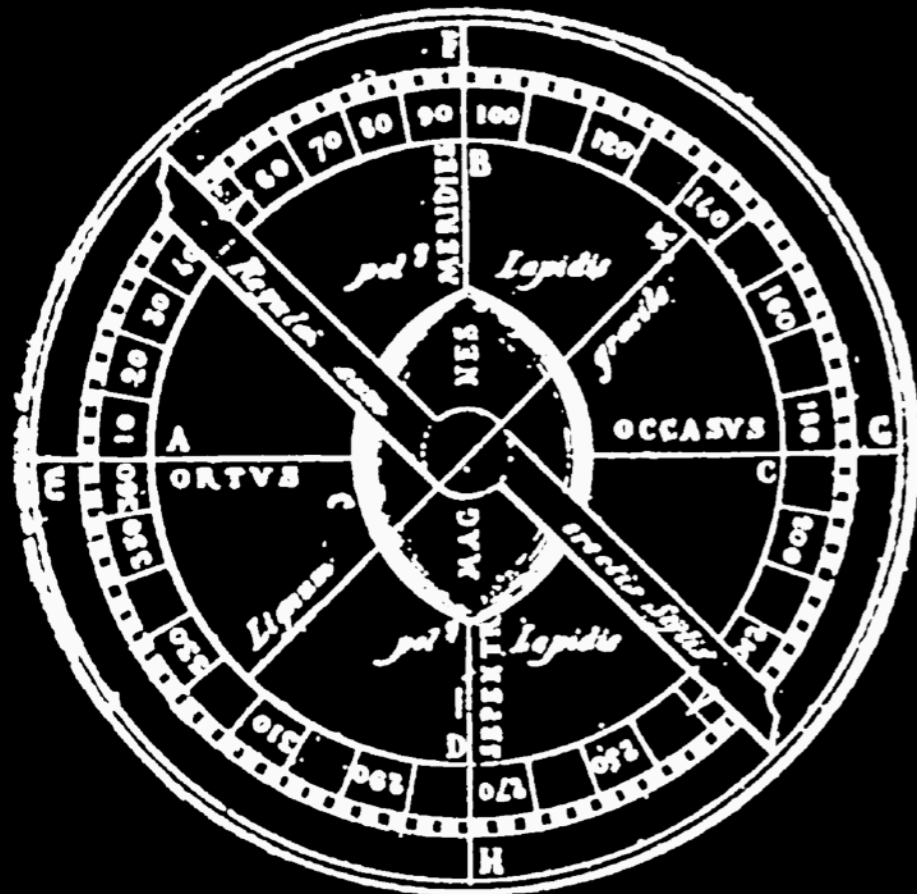


FIG. I.—AZIMUTH COMPASS

Pierre de Maricourt (1269)

From the trenches at Lucera:

Magnetism takes off

Lodestone compass (Han Dynasty, ~200 BC)

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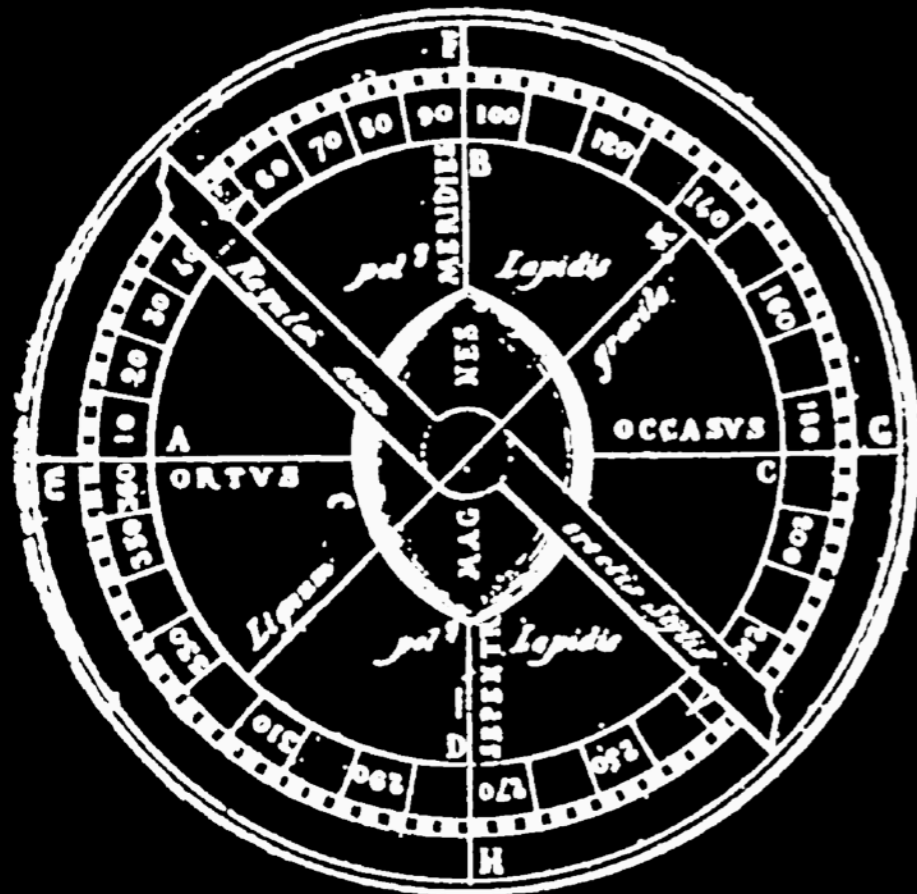


FIG. 1.—AZIMUTH COMPASS

Pierre de Maricourt (1269)

From the trenches at Lucera:

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

William Gilbert

English physician, physicist, natural philosopher



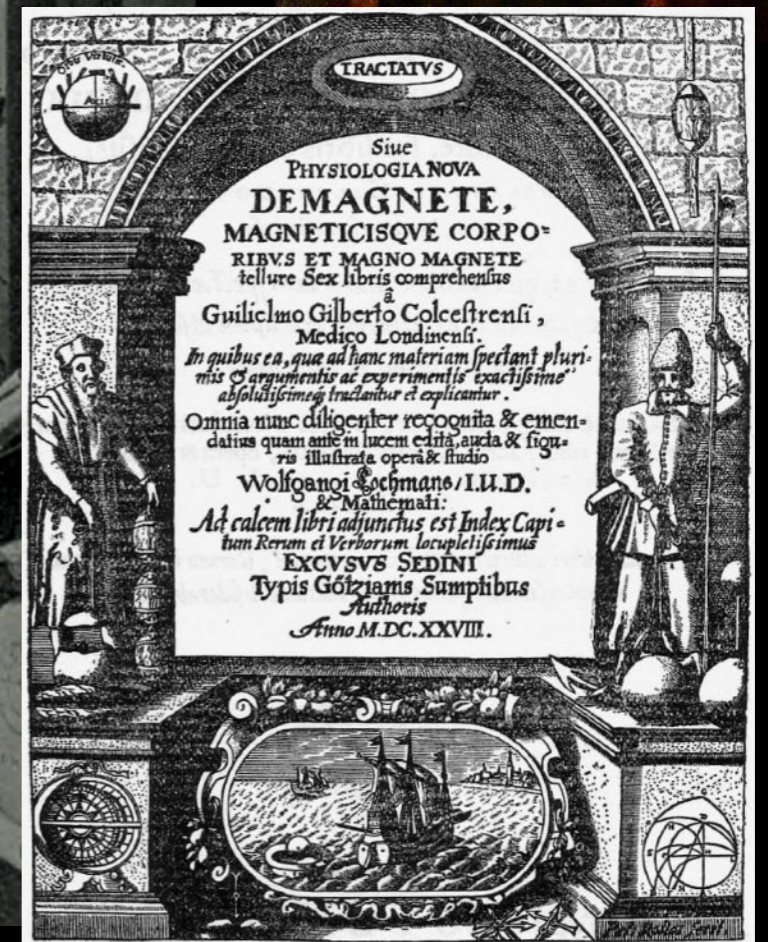
(Late 1500s)



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

William Gilbert

English physician, physicist, natural philosopher



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

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

On the attraction of amber

On the attraction of amber

“And now, what is it that produces the movement?”

On the attraction of amber

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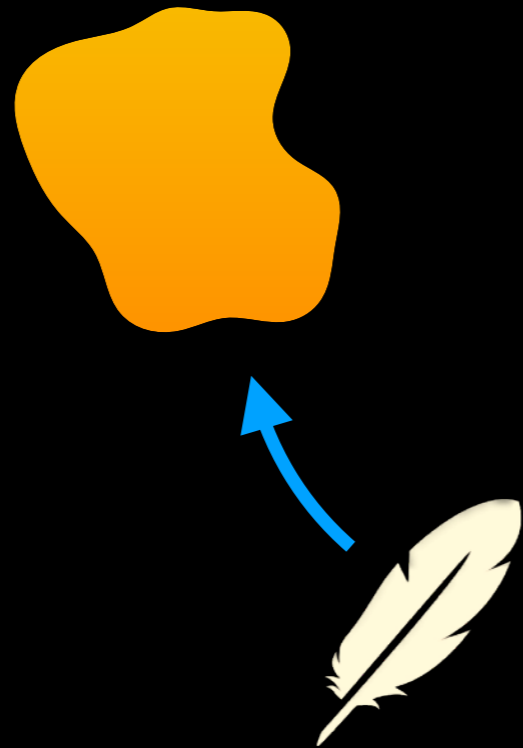
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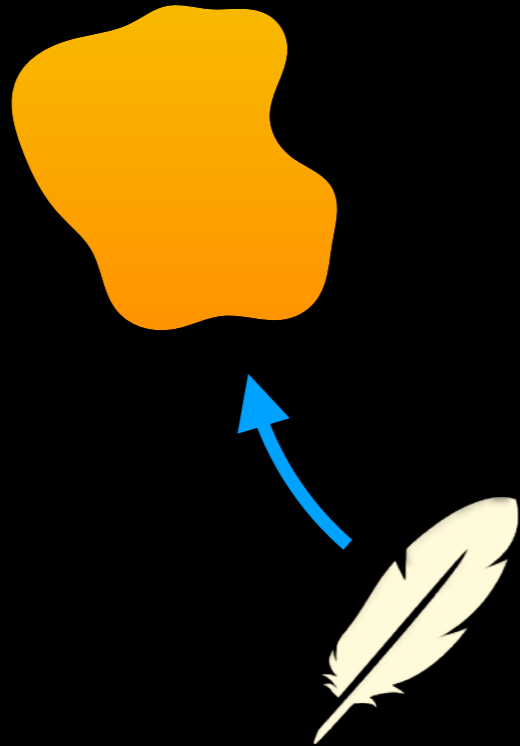
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On the attraction of amber

“And now, what is it that produces the movement?”

“Is something imperceptible for us flowing out of the substance into the ambient air?”

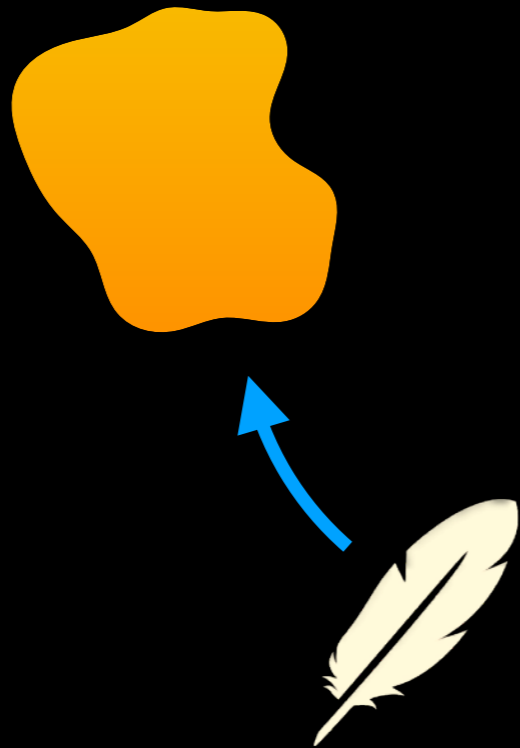


On the attraction of amber

“And now, what is it that produces the movement?”

“Is something imperceptible for us flowing out of the substance into the ambient air?”

“And if it is an effluvium, does the effluvium set the air in current, and is the current then followed by the bodies?”

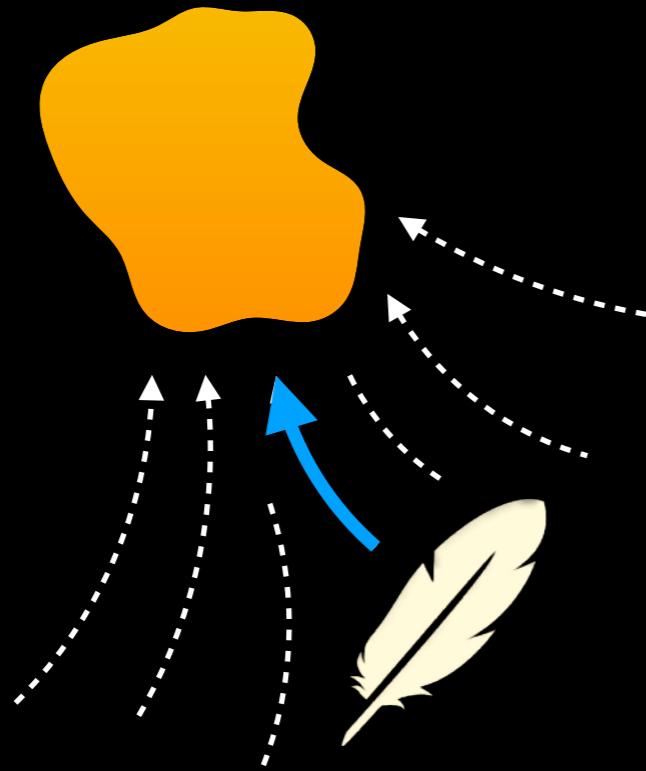


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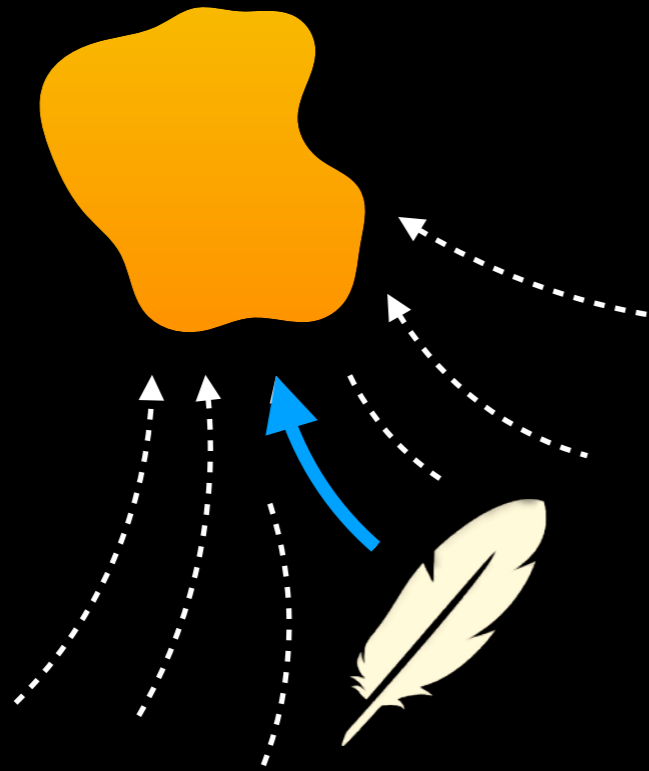
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“An amber that will attract bodies from a considerable radius will cause no motion to a candle flame.”



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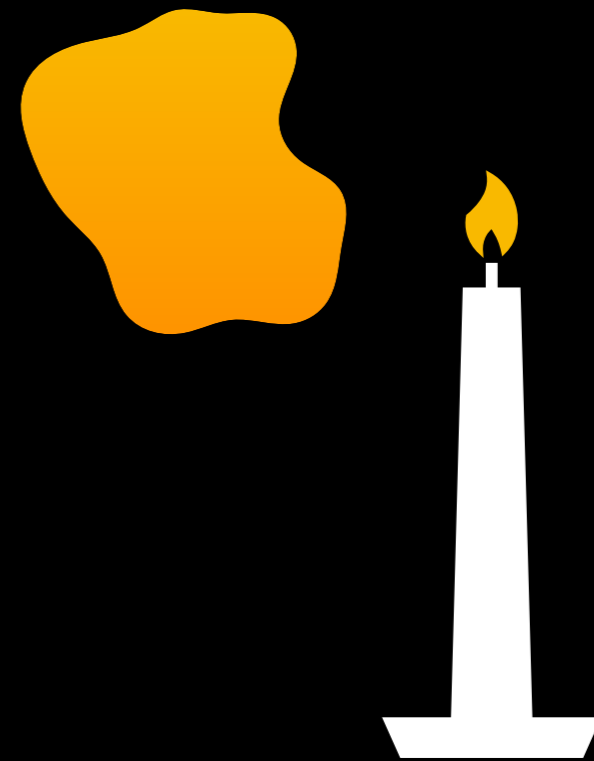
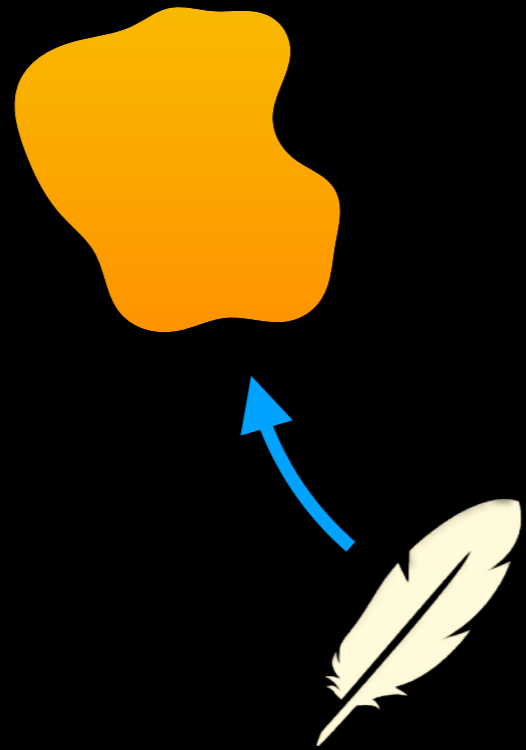
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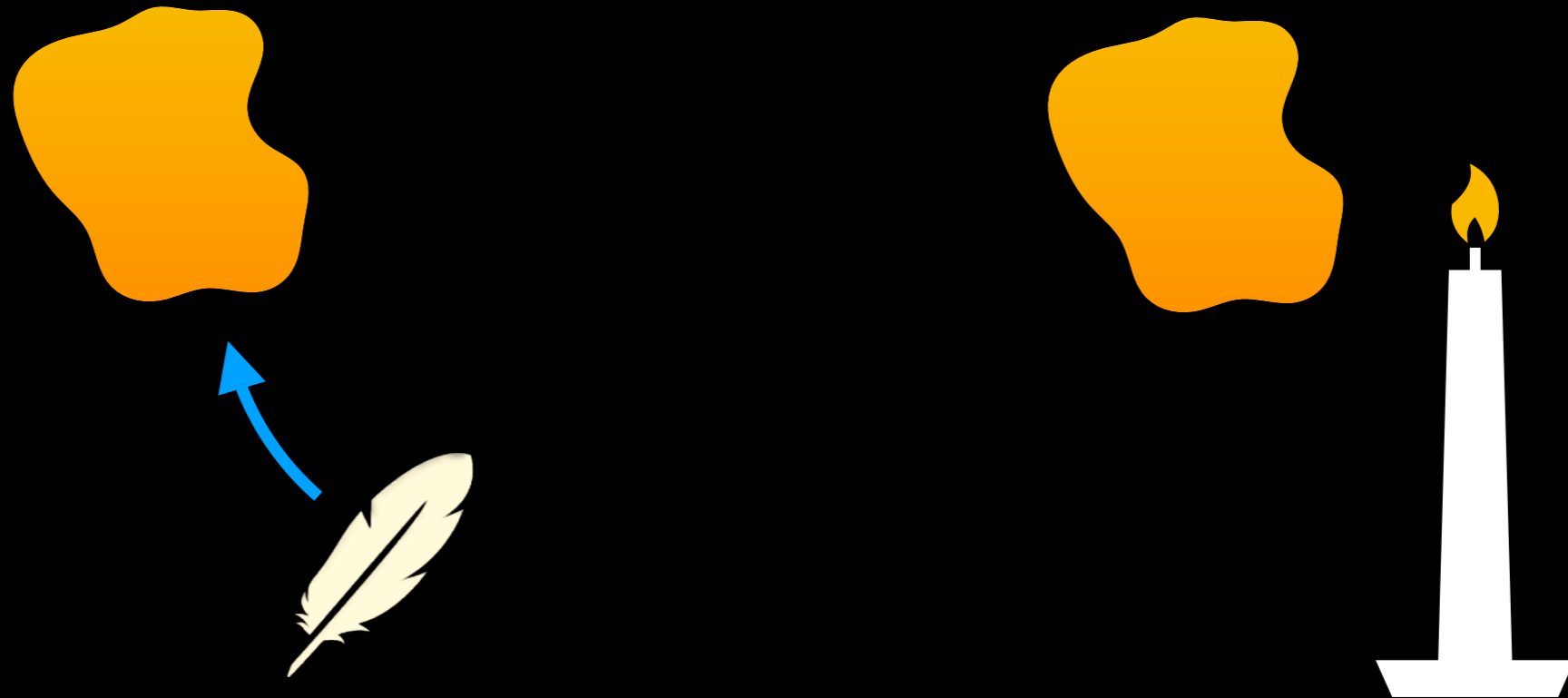


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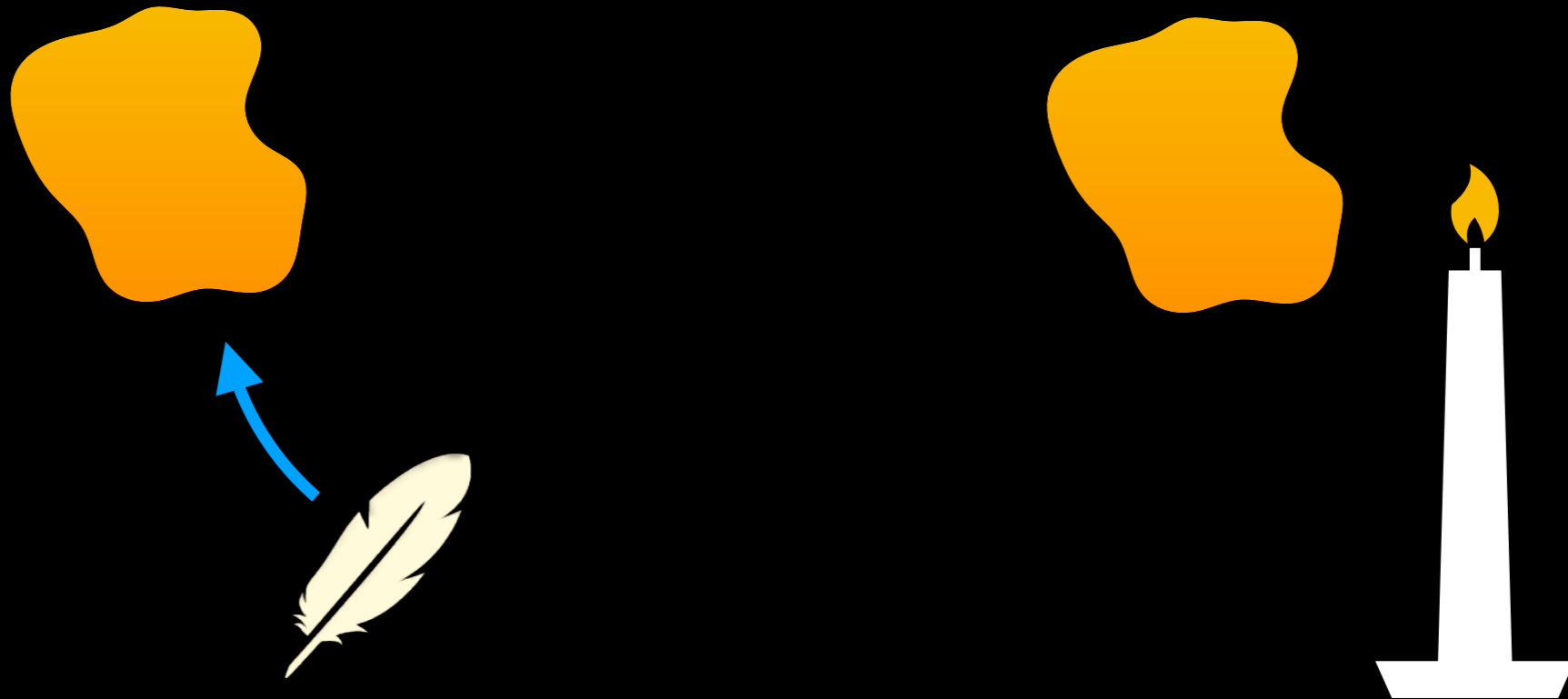
“Or is it the bodies themselves directly that are drawn up?”



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“Or is it the bodies themselves directly that are drawn up?”

“If so, then supposing its surface is clean and free of adhesions, what need is there of friction?”

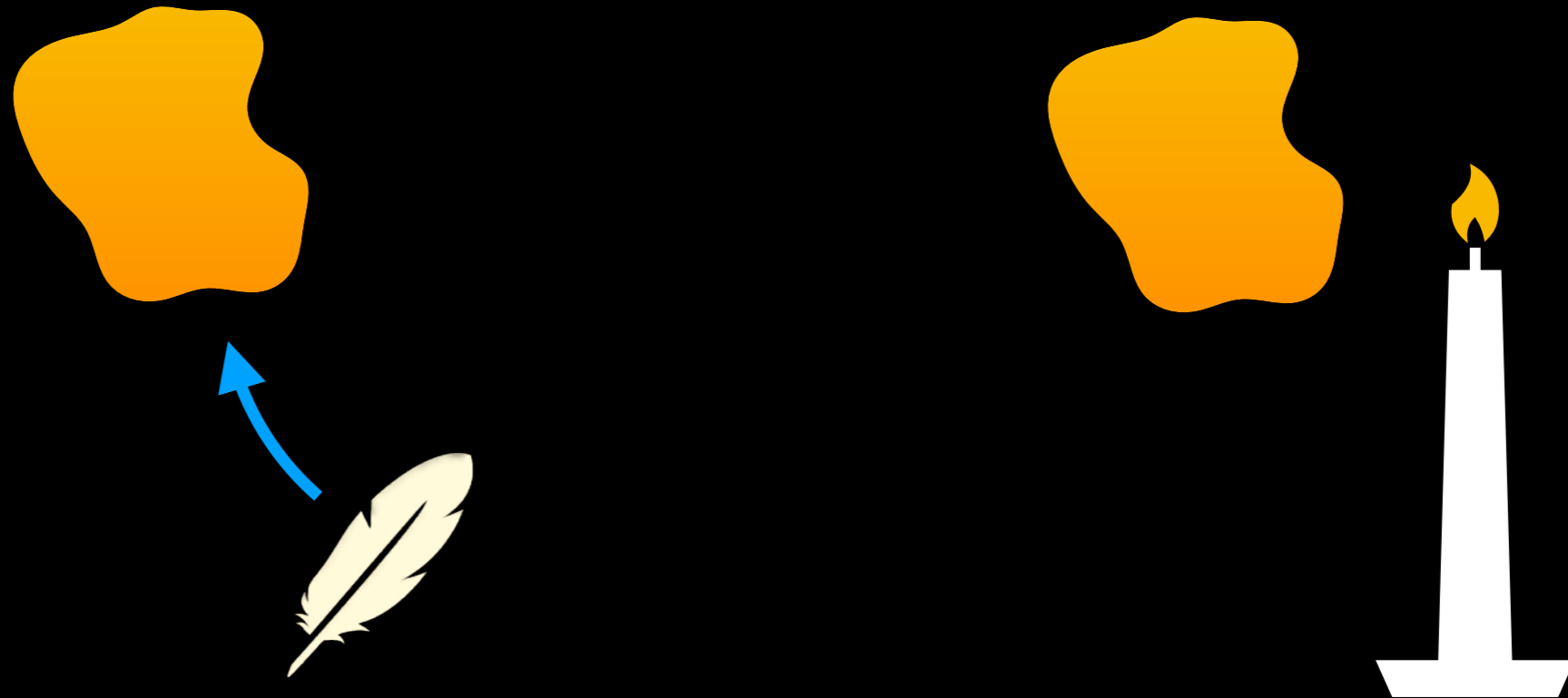


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“Or is it the bodies themselves directly that are drawn up?”

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“For as no action can be preformed by matter save by contact, these electric bodies do not appear to touch, but of necessity something is given out from the one to the other [...]”



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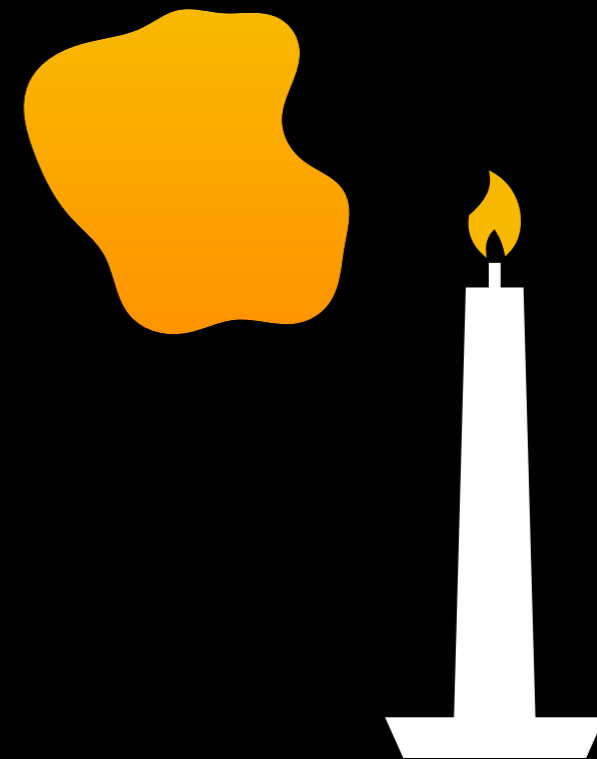
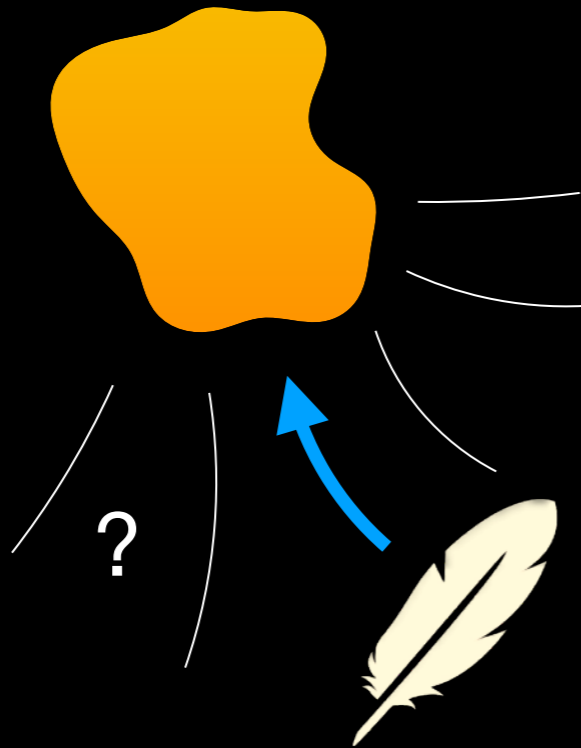
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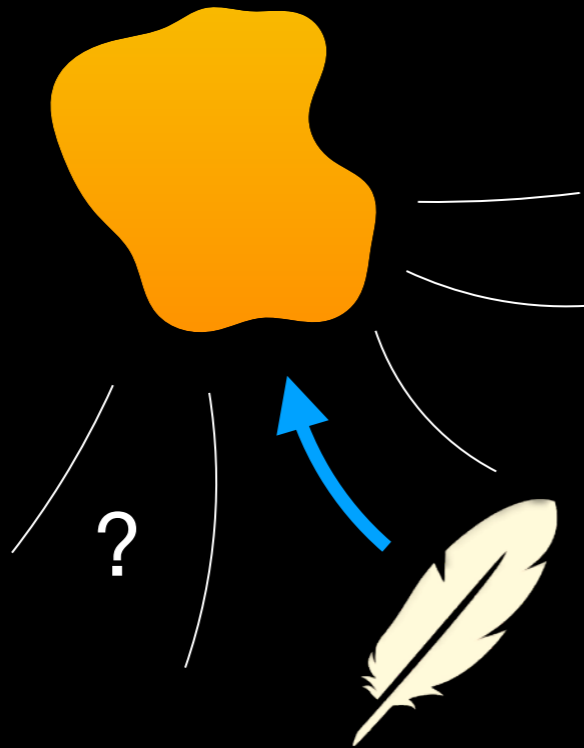
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“Action at a distance”

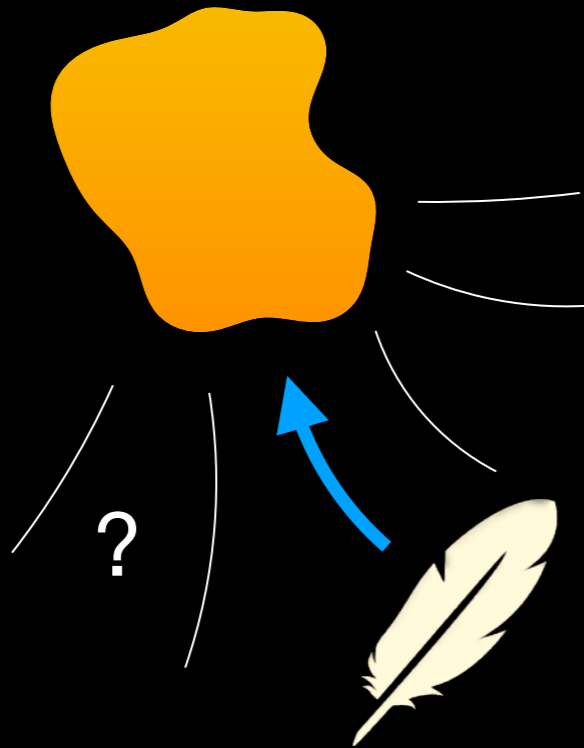


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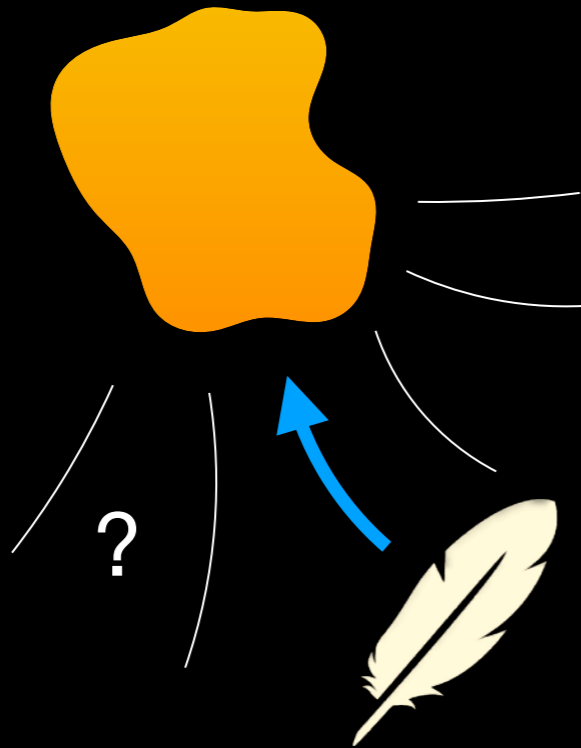
Amber is not special!



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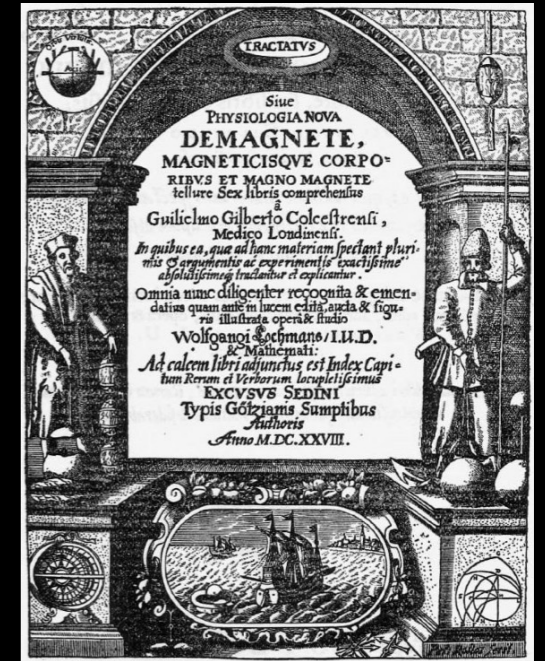
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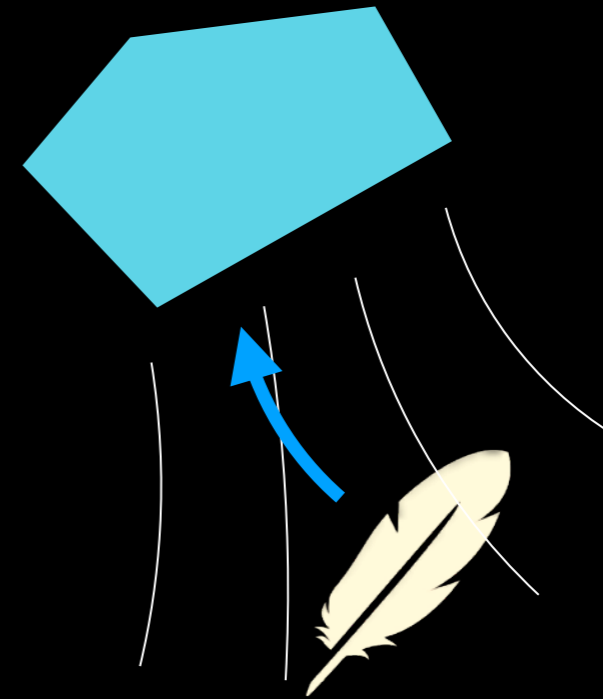
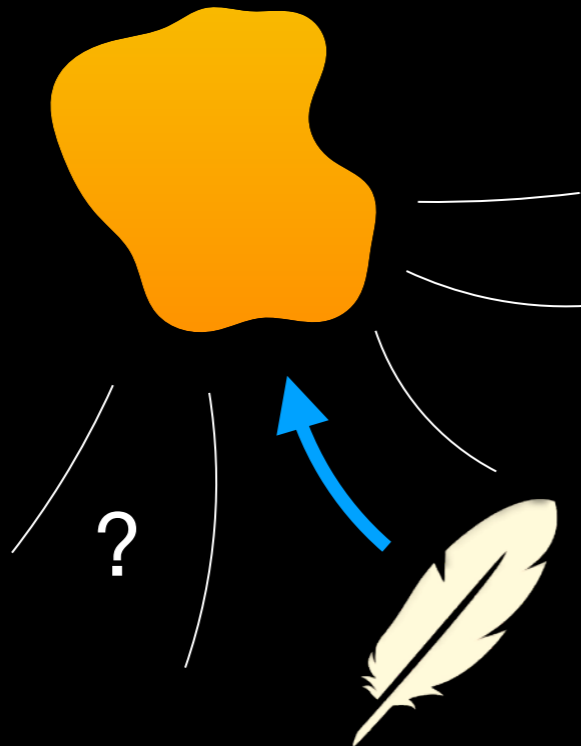
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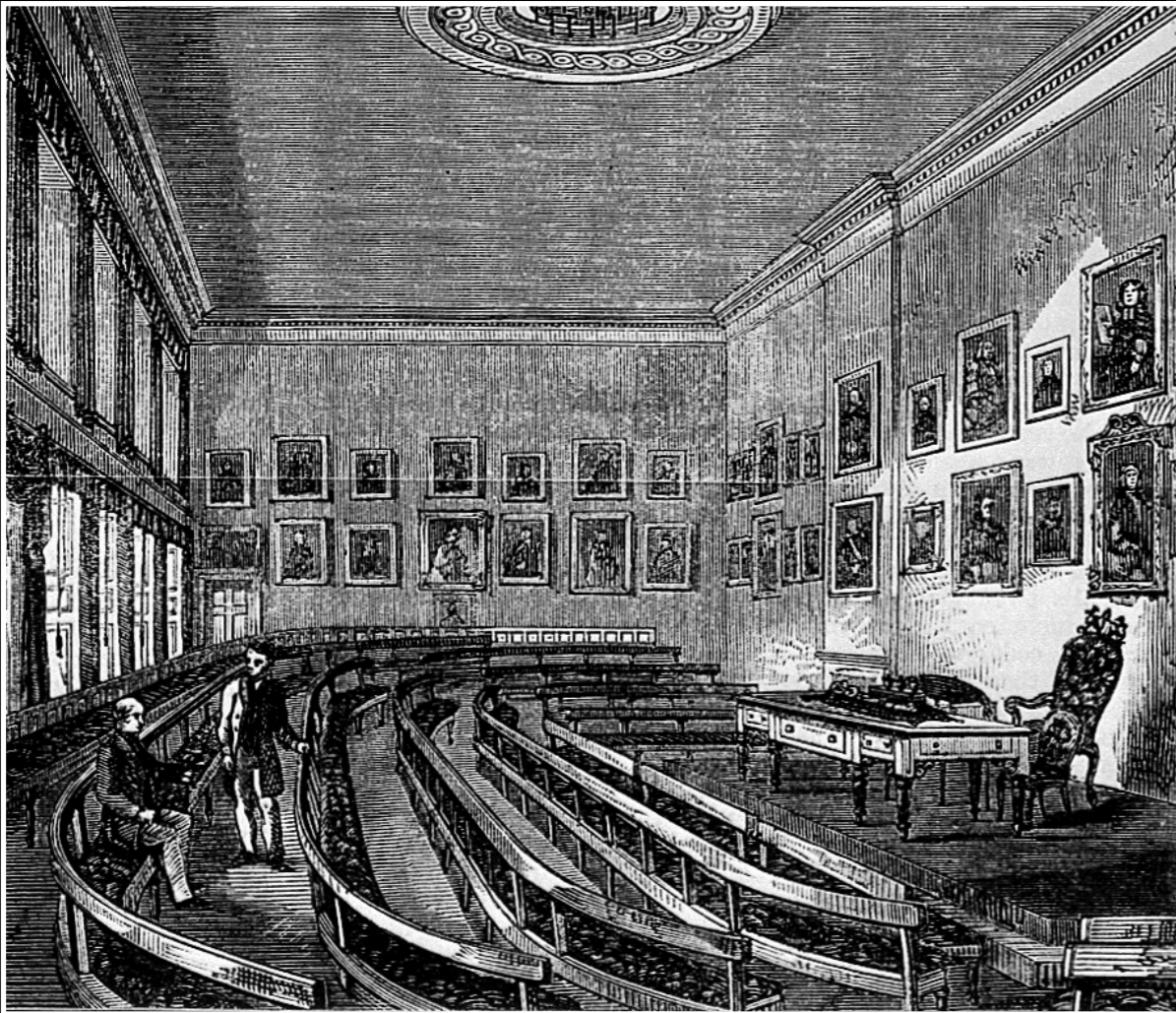


Francis Hauksbee

Draper, instrument maker, laboratory assistant

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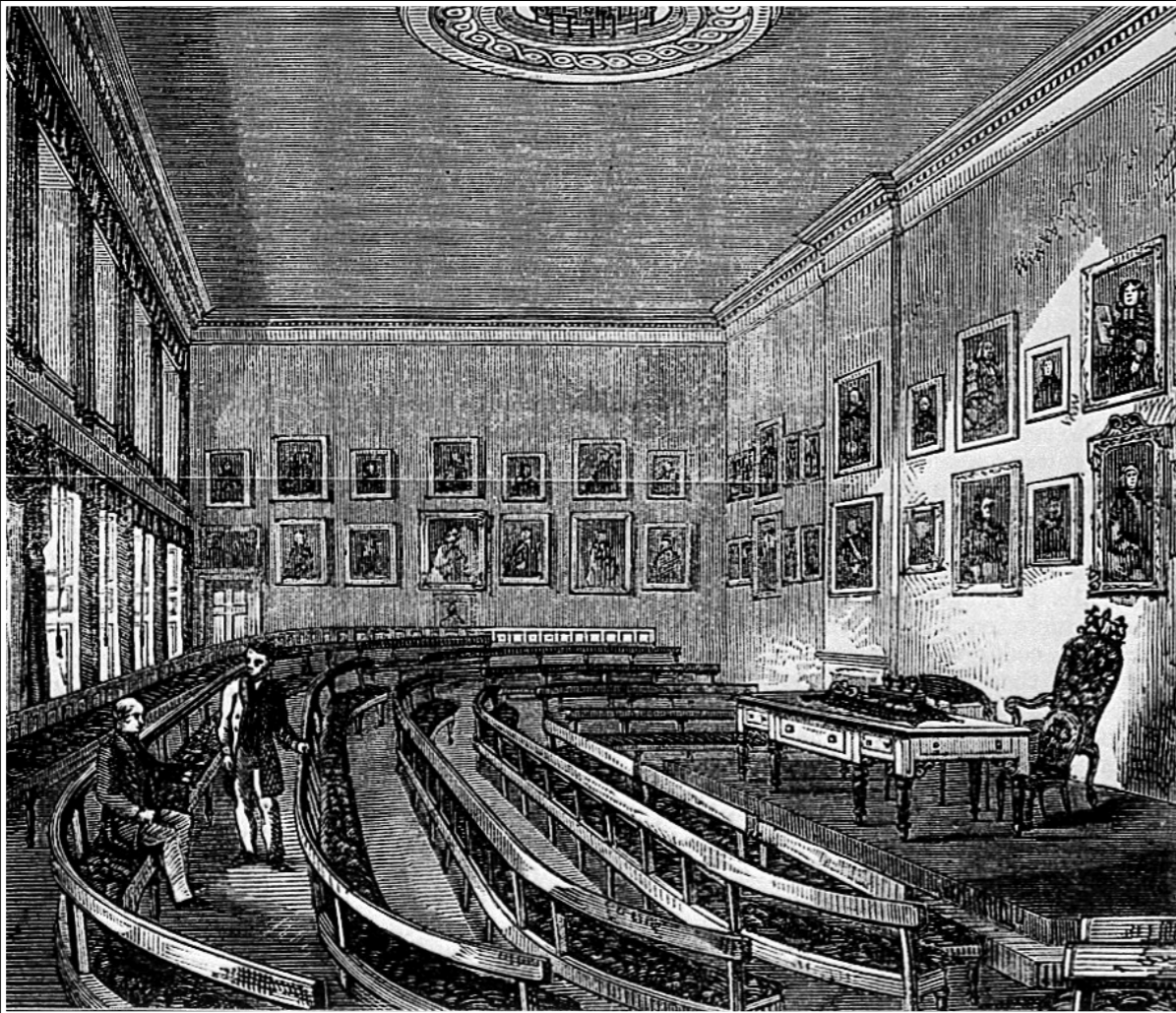
Draper, instrument maker, laboratory assistant



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

Francis Hauksbee

Draper, instrument maker, laboratory assistant



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

Collected experiments,
published 1709

Physico-Mechanical **EXPERIMENTS**

On Various Subjects.

CONTAINING

An Account of several Surprizing *Phenomena*

TOUCHING

Light and Electricity,

Producibile on the *Attrition* of BODIES.

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

Together with

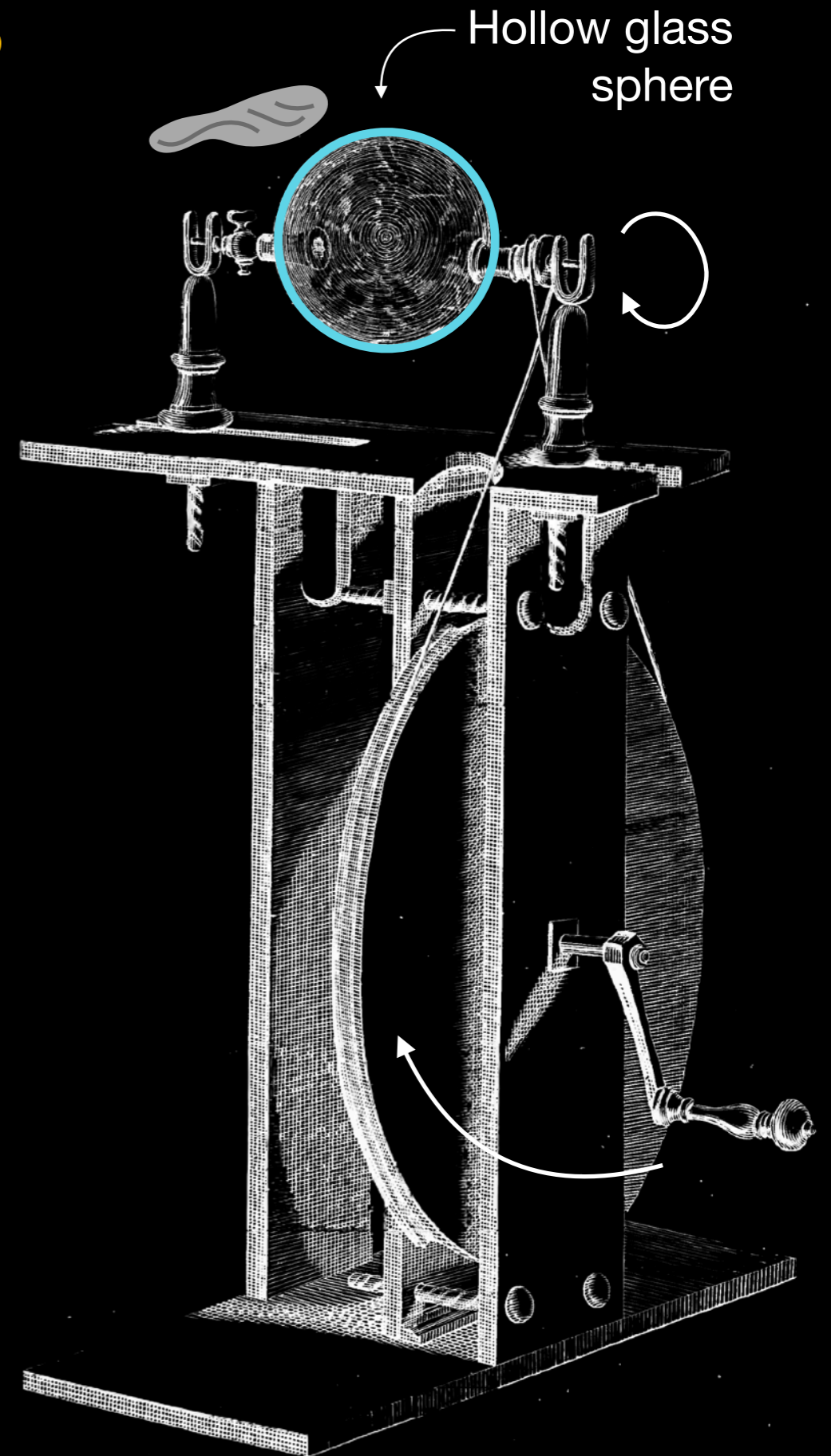
The Explanations of all the MACHINES,
(the Figures of which are Curiously Engrav'd on
Copper) and other APPARATUS us'd in making
the EXPERIMENTS.

By F. HAUKS BEE, F. R. S.

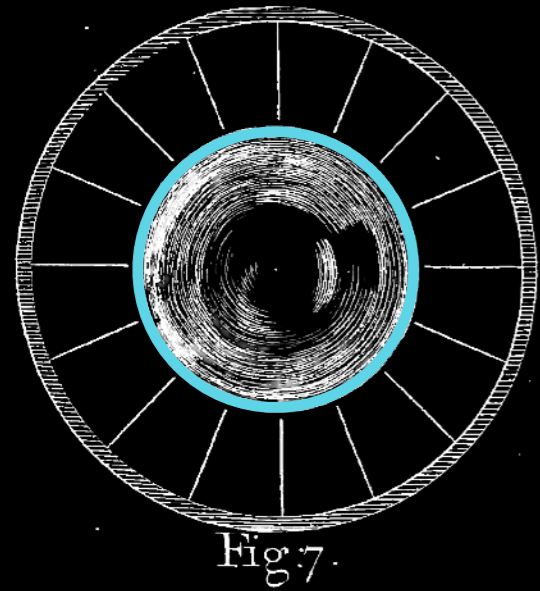
L O N D O N,

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

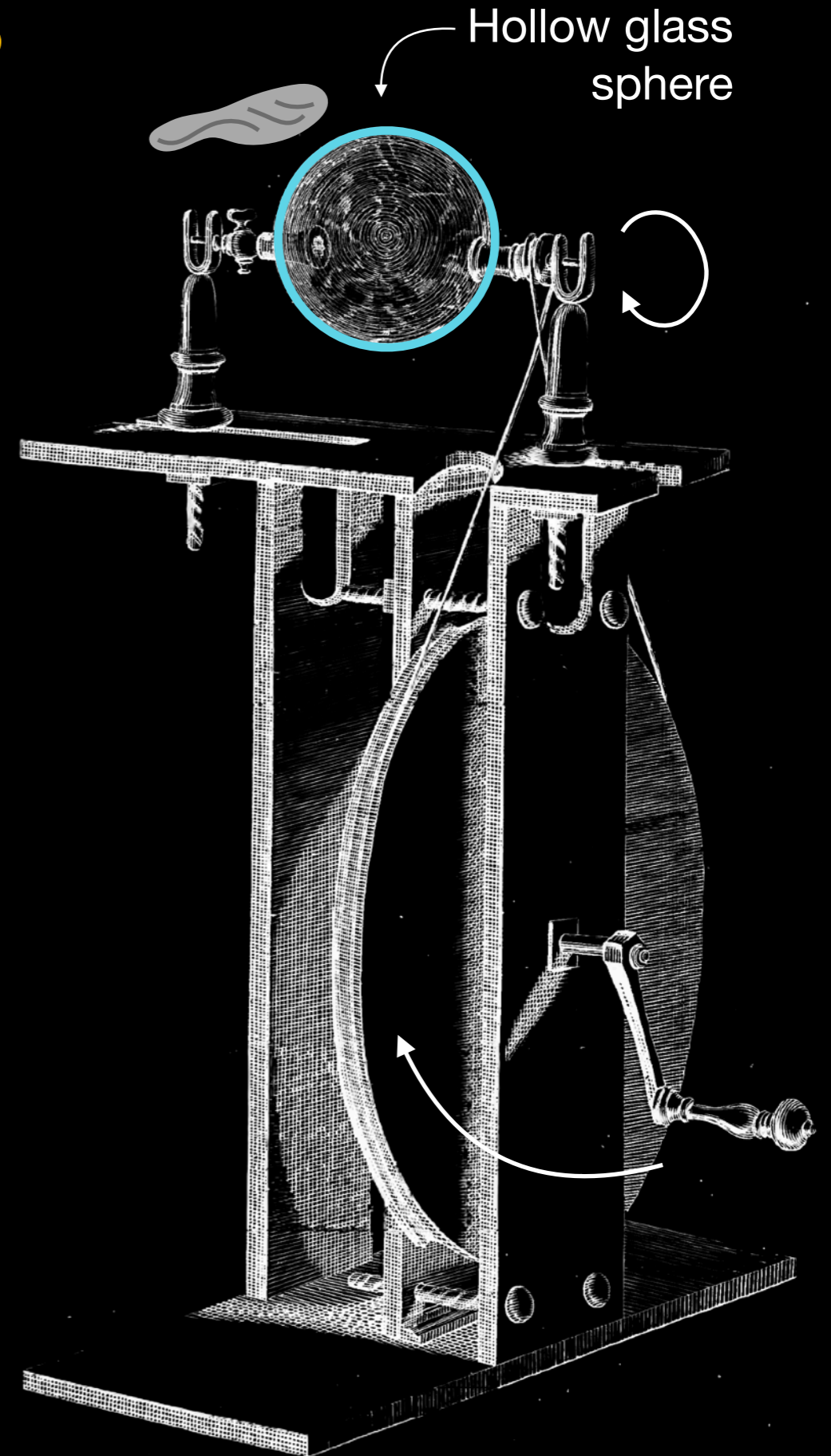
Hauksbee's experiments



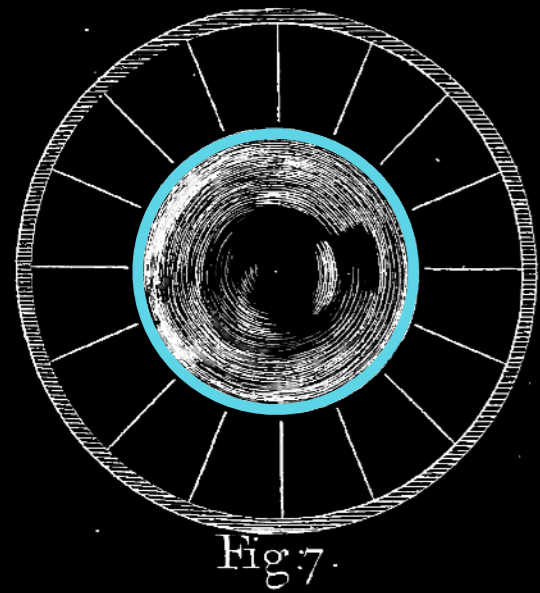
Hauksbee's experiments



“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.”

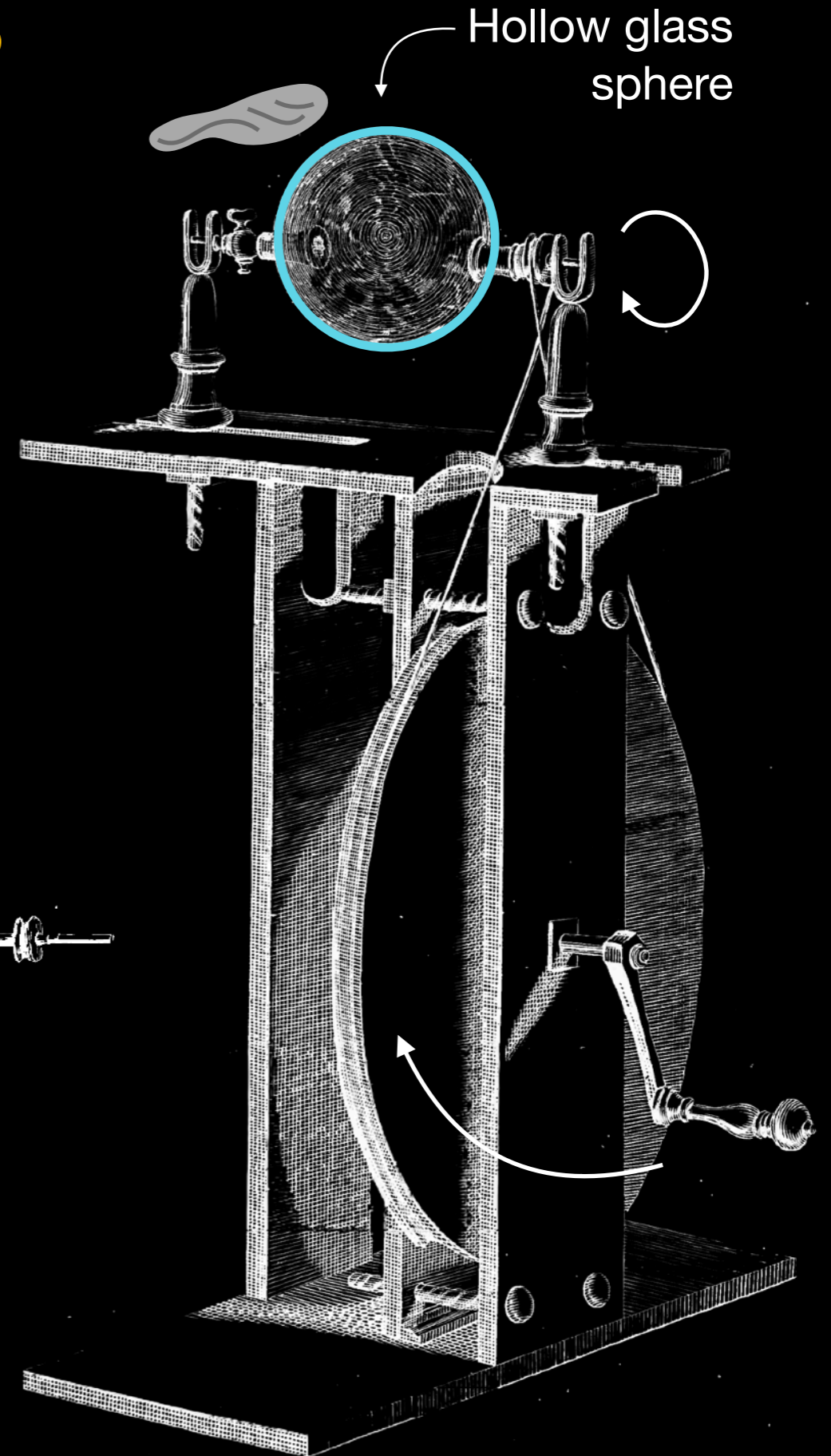
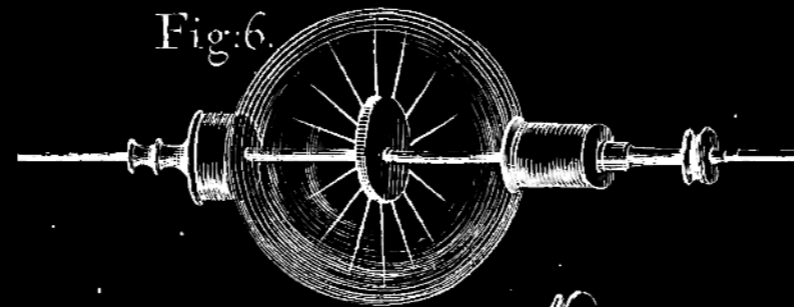


Hauksbee's experiments

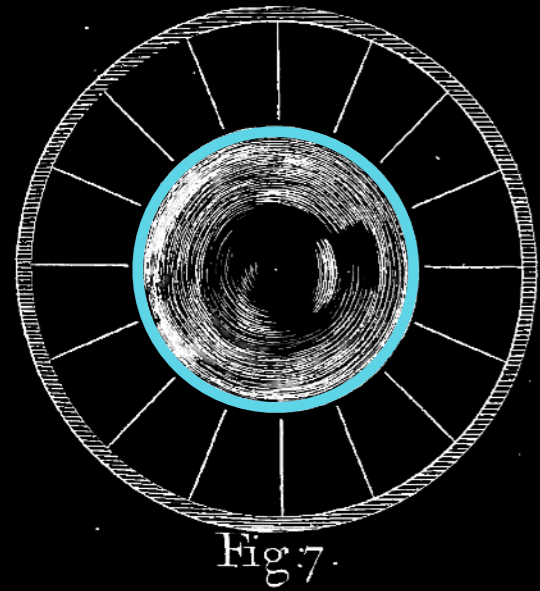


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"The threads here issued like rays, from a center outwards."

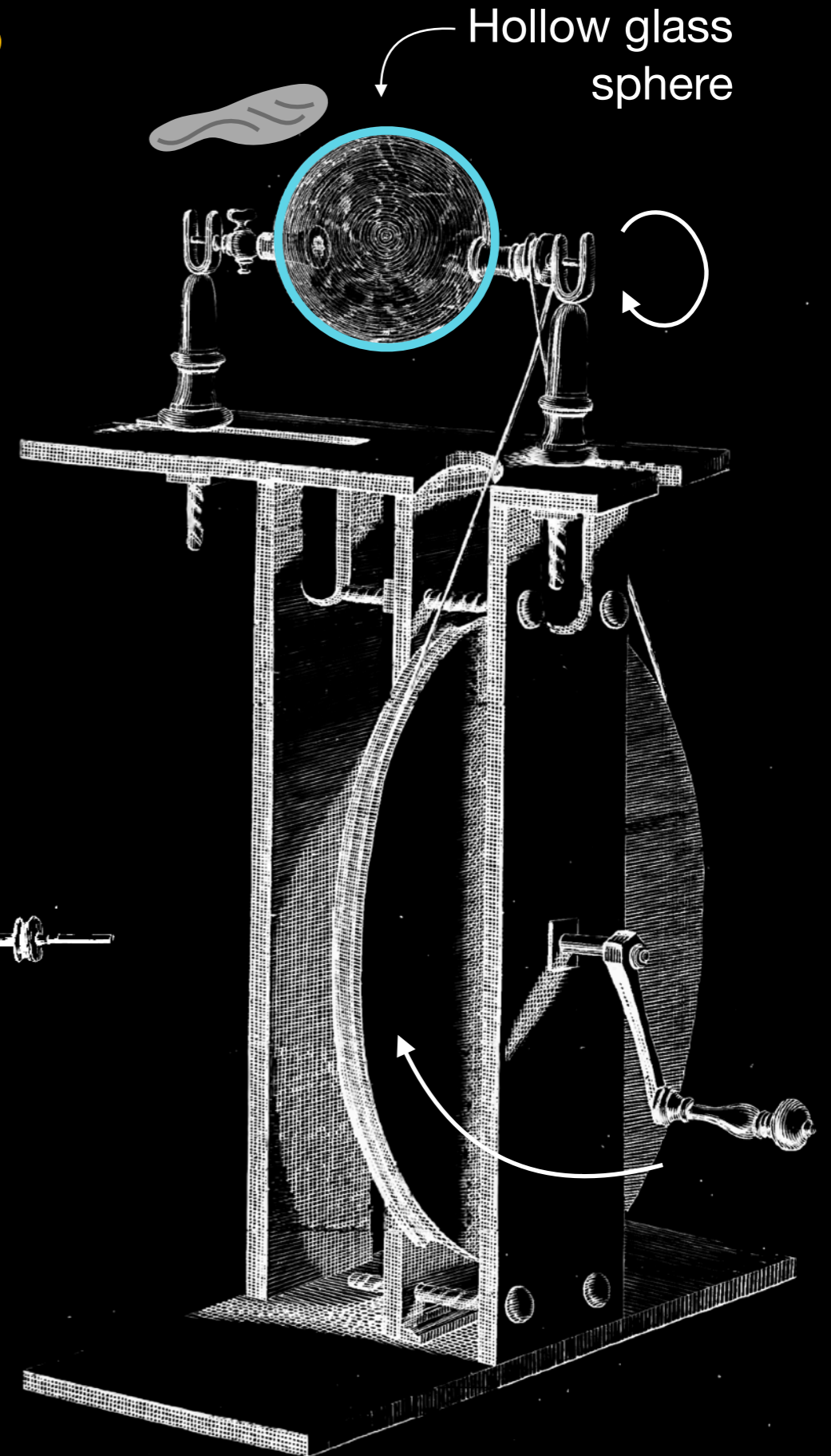
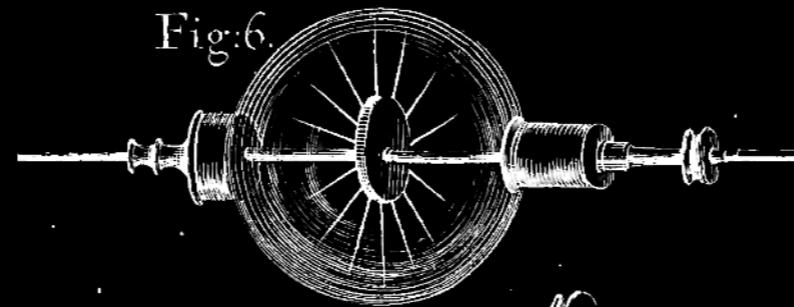


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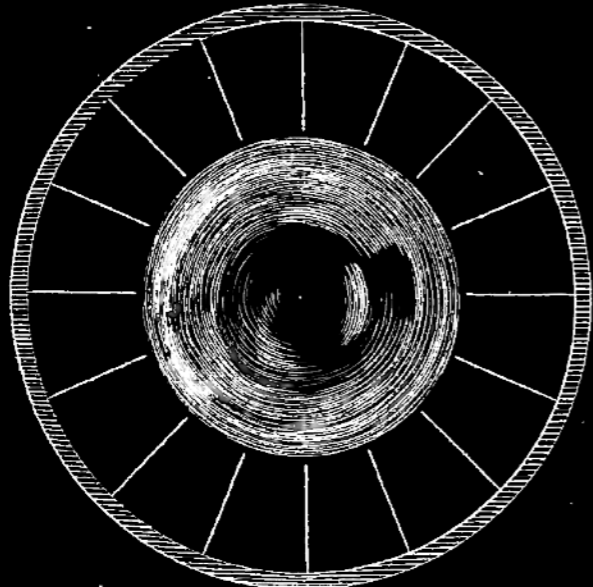


Fig:7.

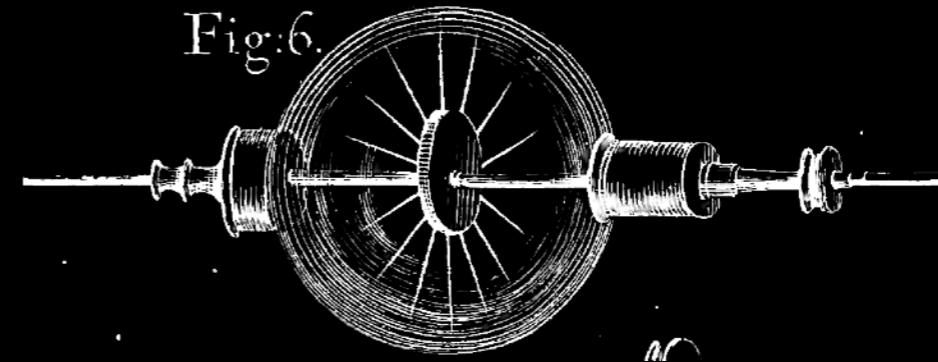
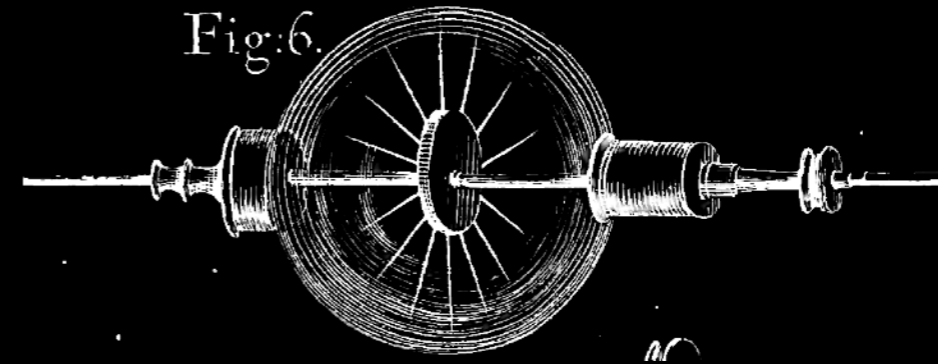
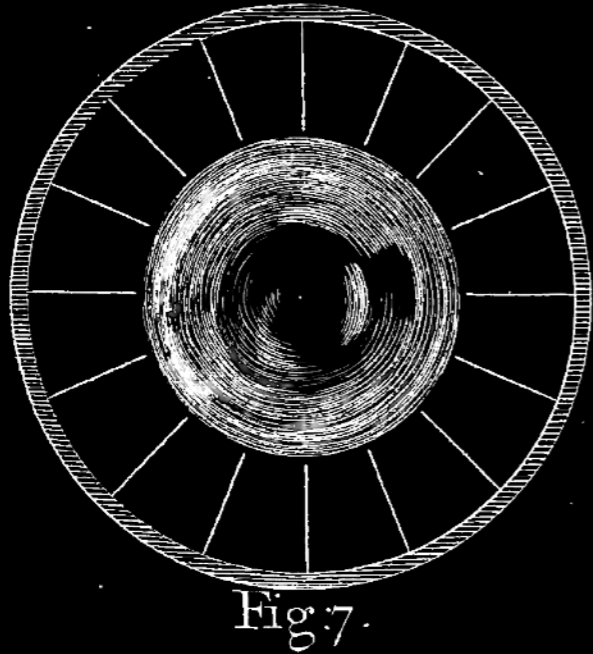


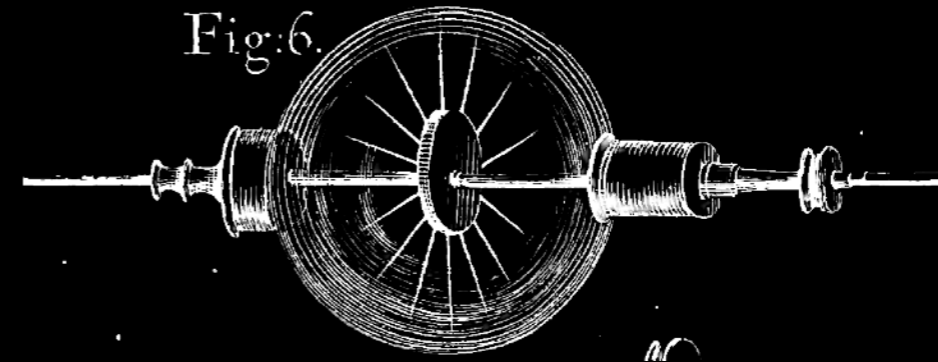
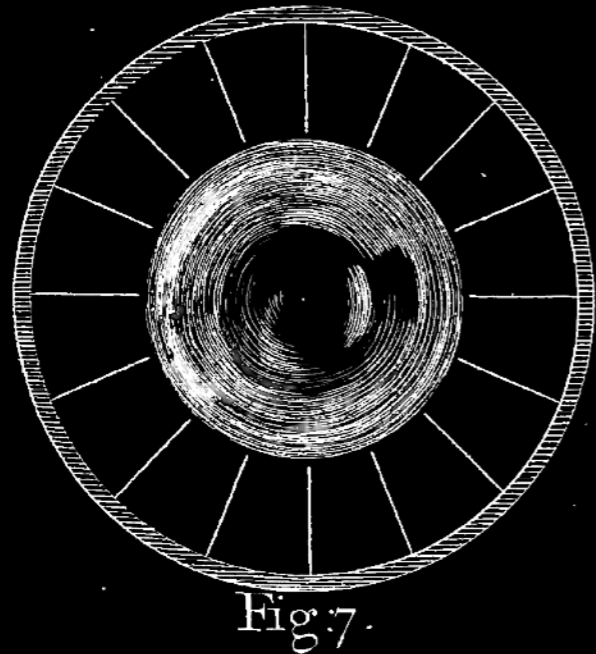
Fig:6.

Hauksbee's experiments



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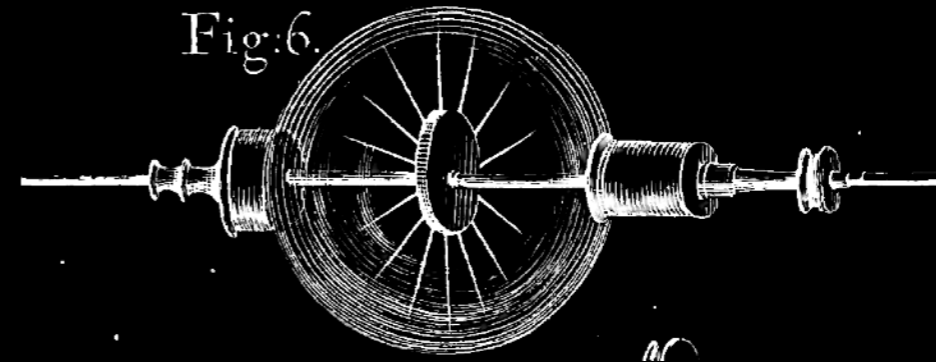
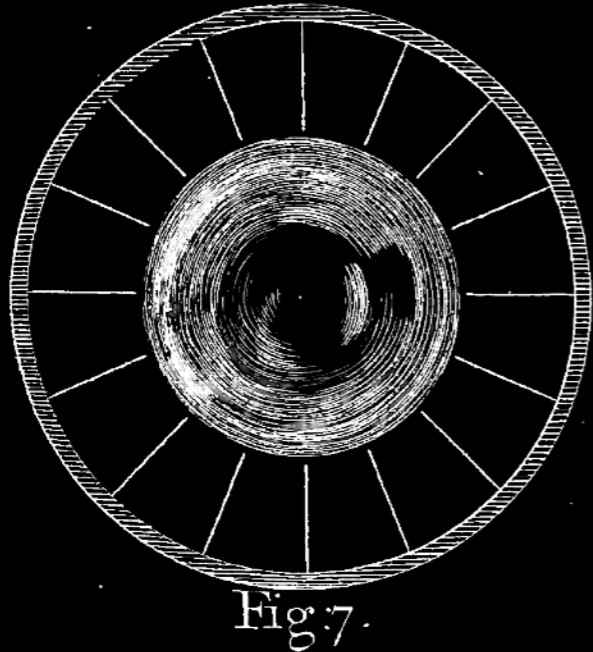
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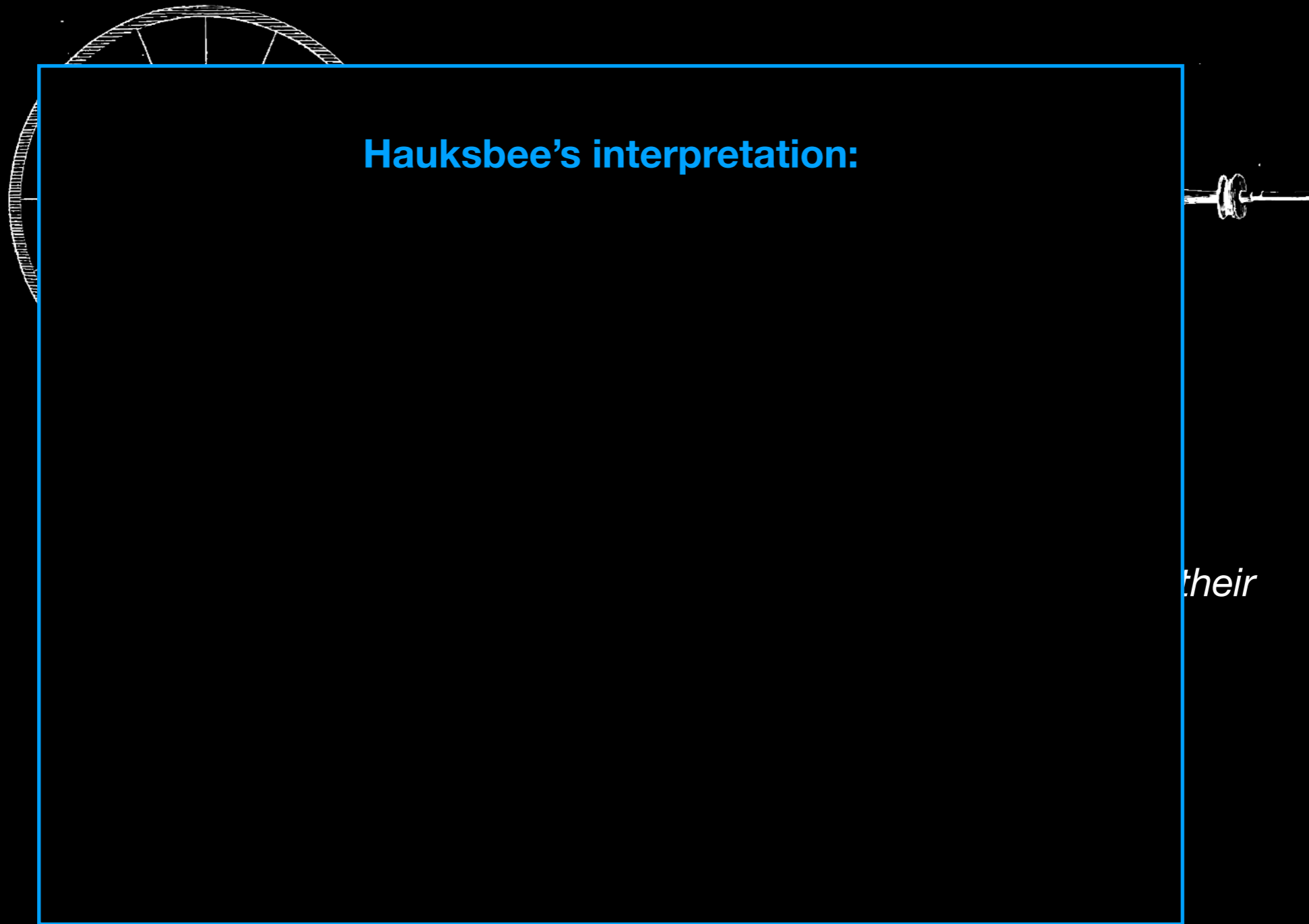


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Electricity as matter?

"Electric spiderweb"

Stephen Gray

Cloth-dyer, hobby astronomer

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John Flamsteed,
Astronomer Royal at Greenwich



Stephen Gray

Cloth-dyer, hobby astronomer



John Desaguliers,
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Stephen Gray

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Charterhouse



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The discovery of conductivity (1729)

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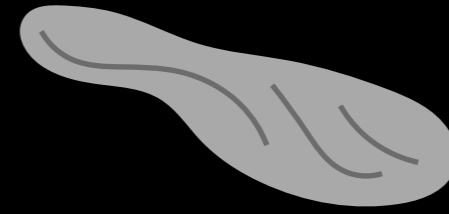
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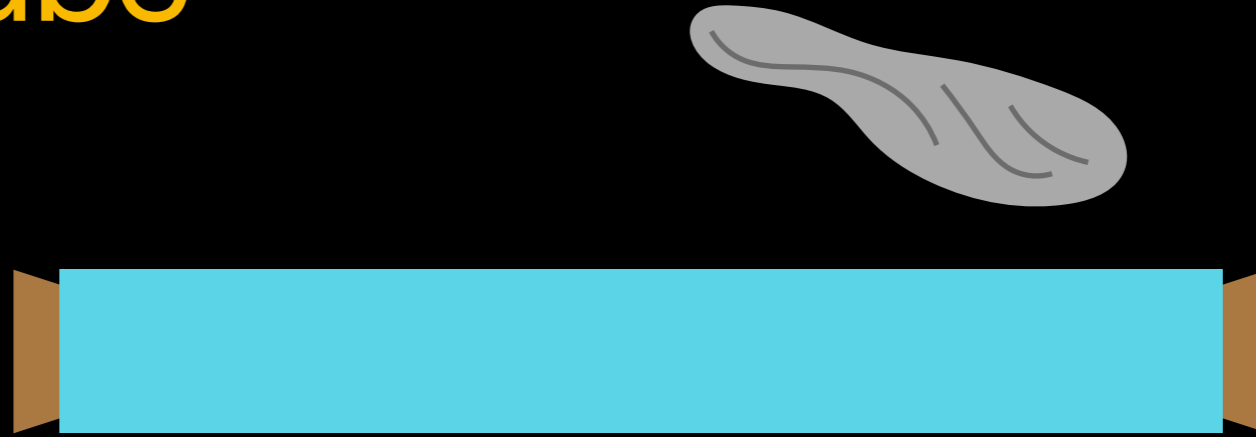
His first try: *“I made several attempts on the metals, to see whether they might not be made attractive by the same method as other bodies were, viz. by heating, rubbing and hammering, but without success.”*

“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

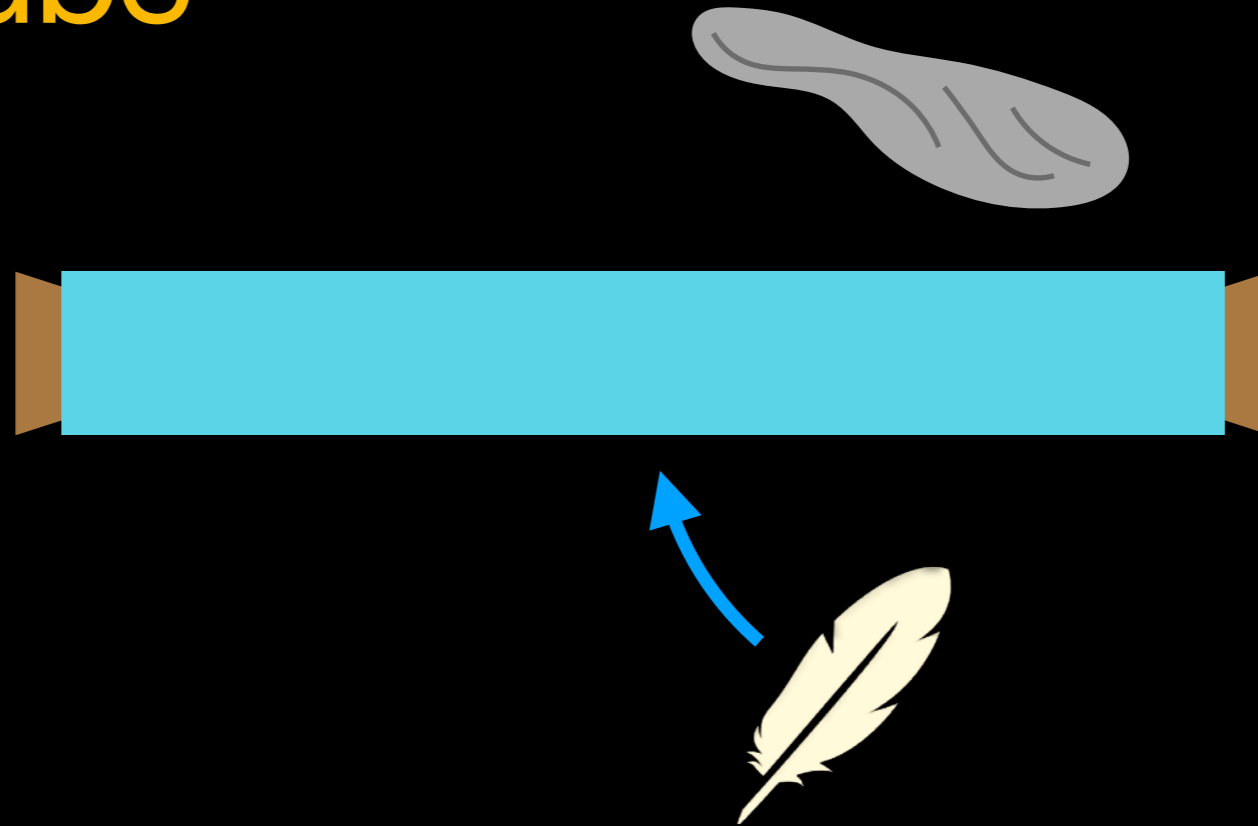


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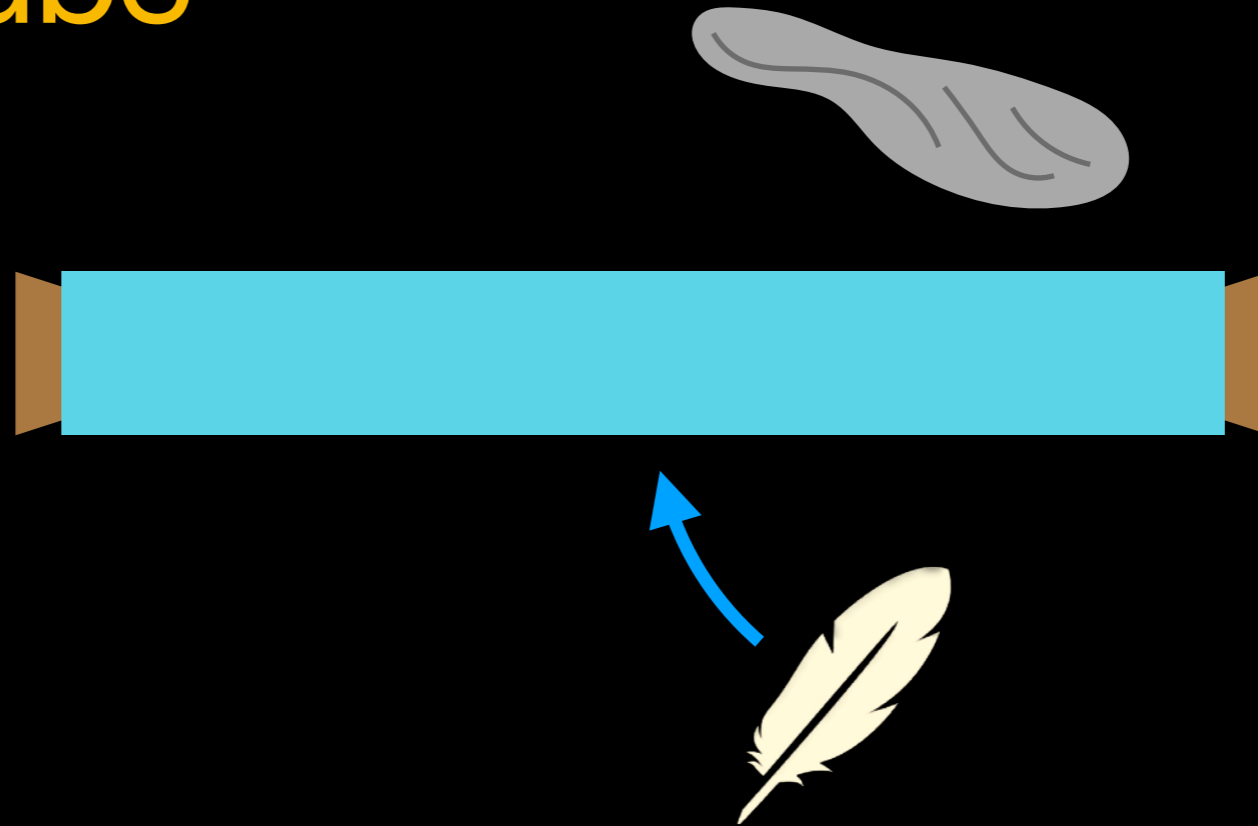
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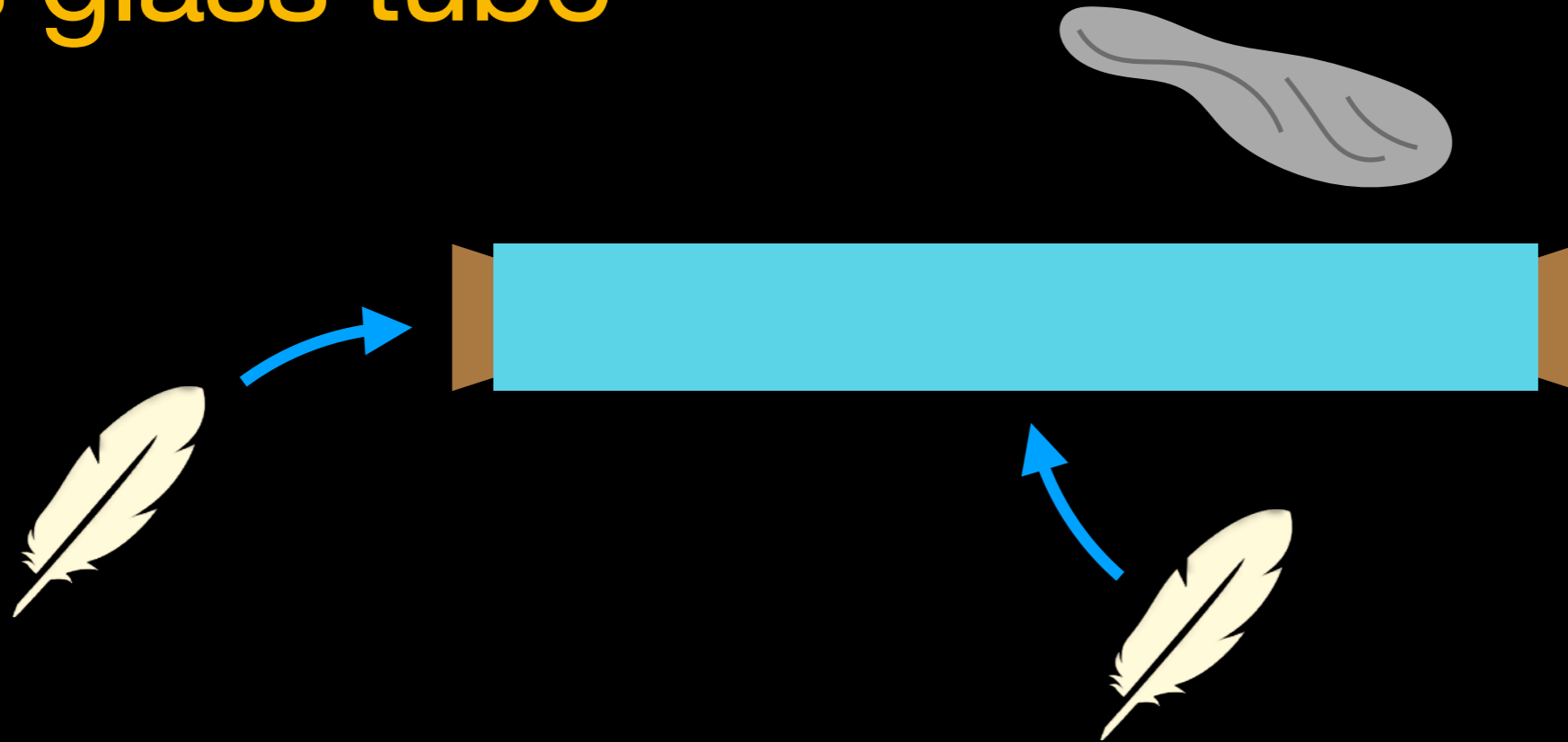
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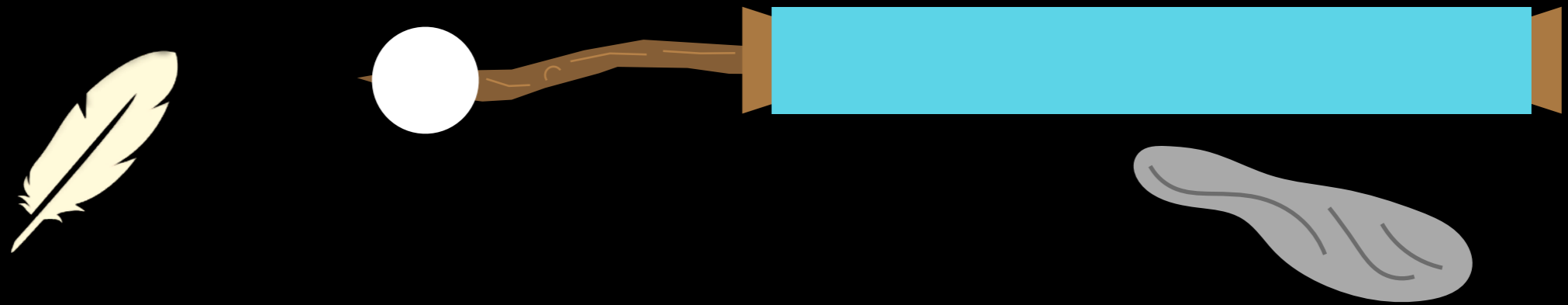
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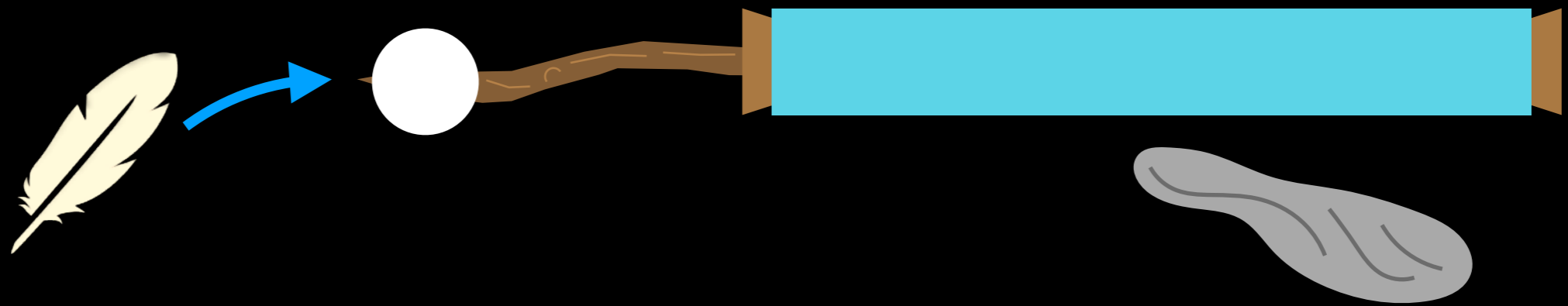
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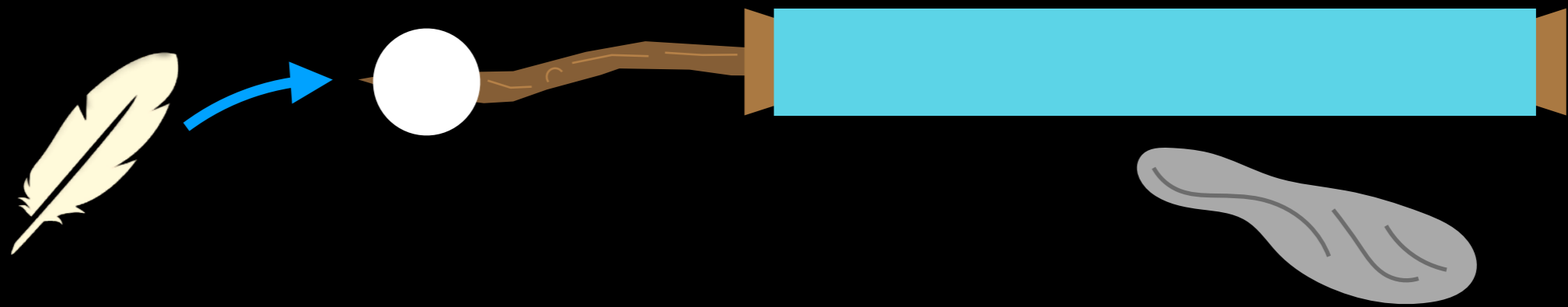
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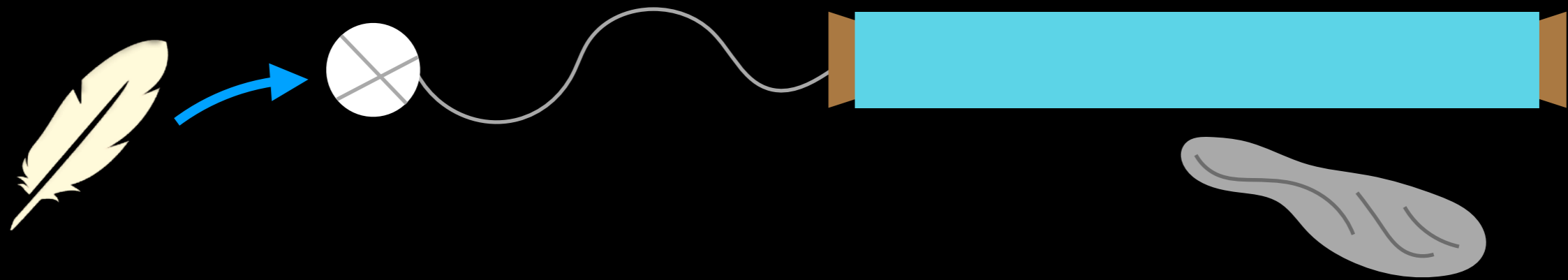
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“I then fixed the ball on longer sticks, first upon one of eight inches, and afterwards upon one of twenty-four inches long, and found the effect the same.”

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“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.”



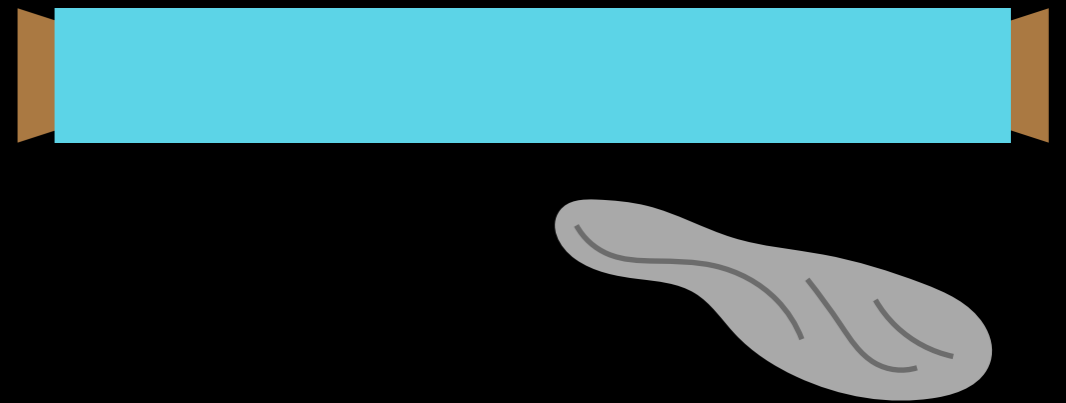
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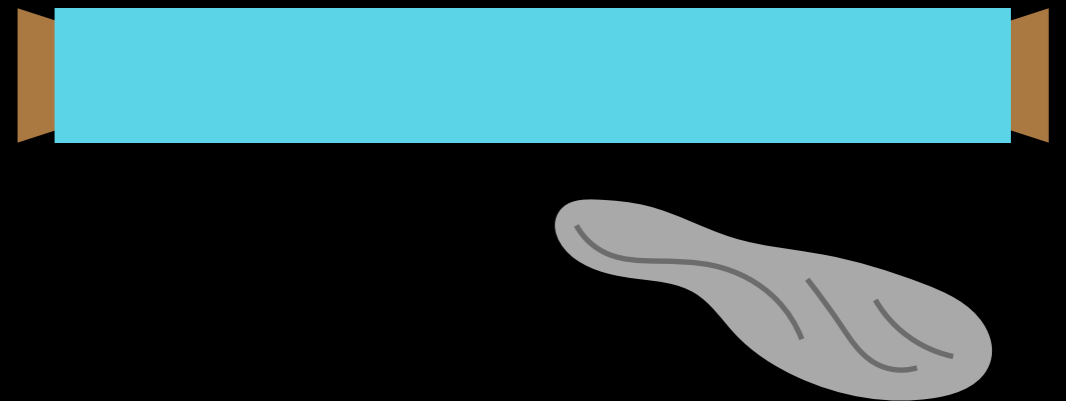
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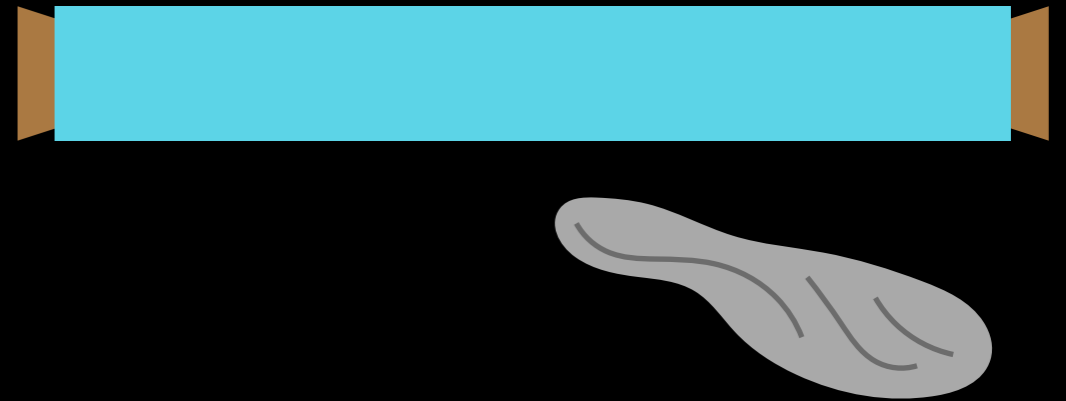
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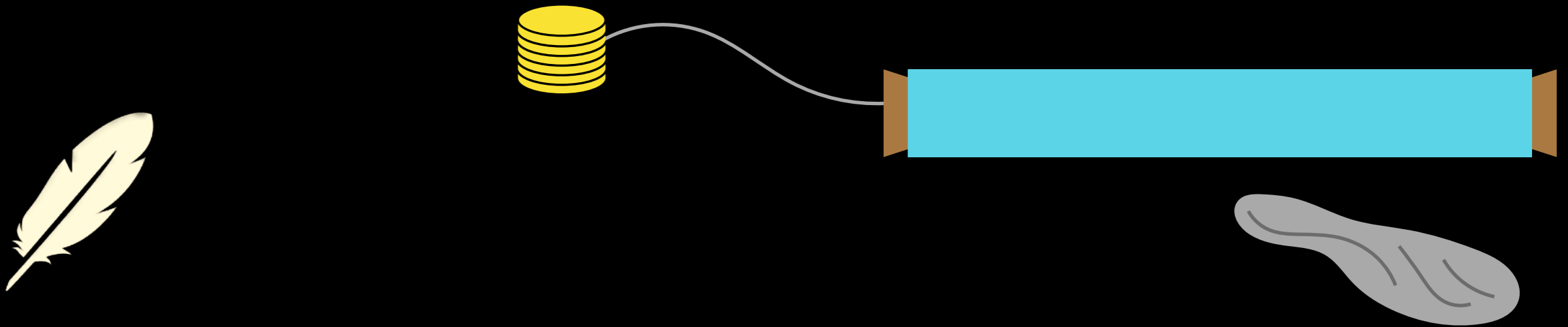
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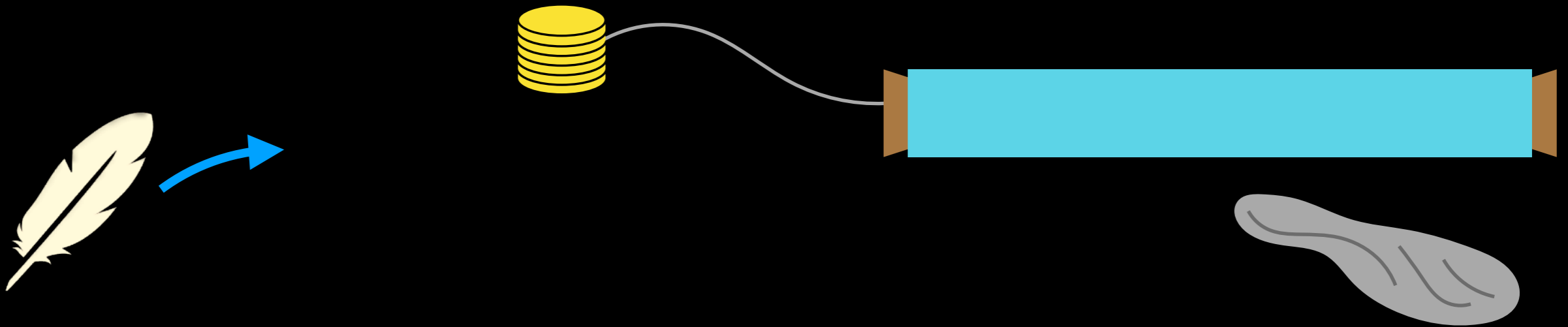
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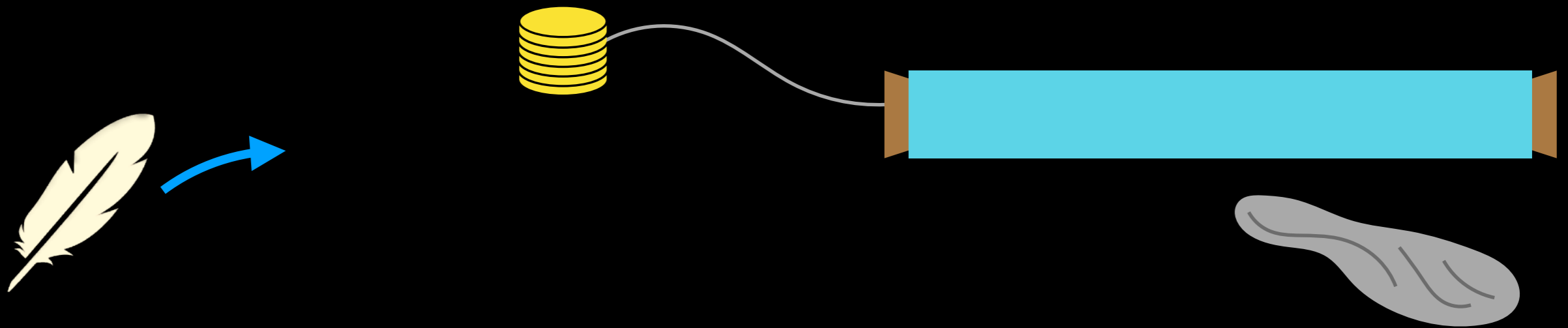
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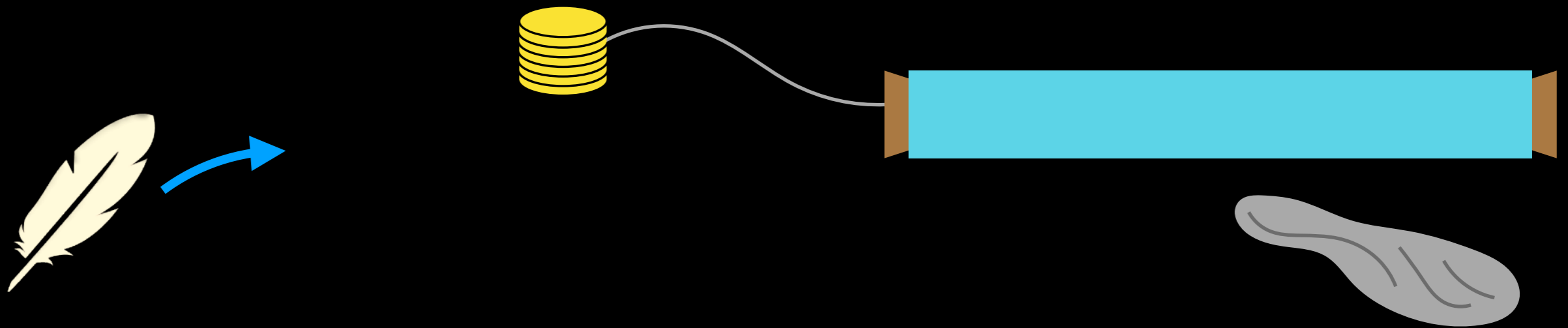
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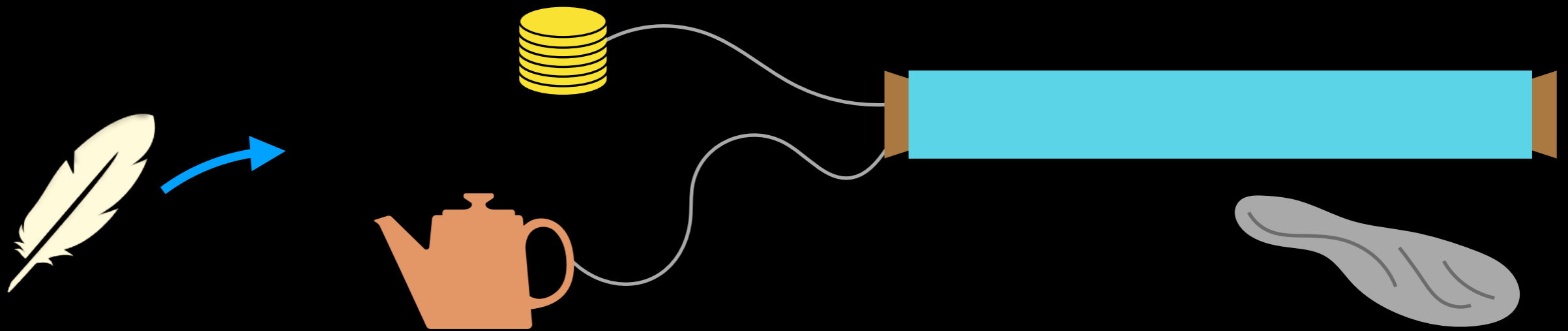
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“Here I made use of a fire-shovel, tongs, and iron poker, a copper tea kettle, which succeeded the same, whether empty, or full of either cold or hot water; a silver pint pot; all which were strongly electrical.”

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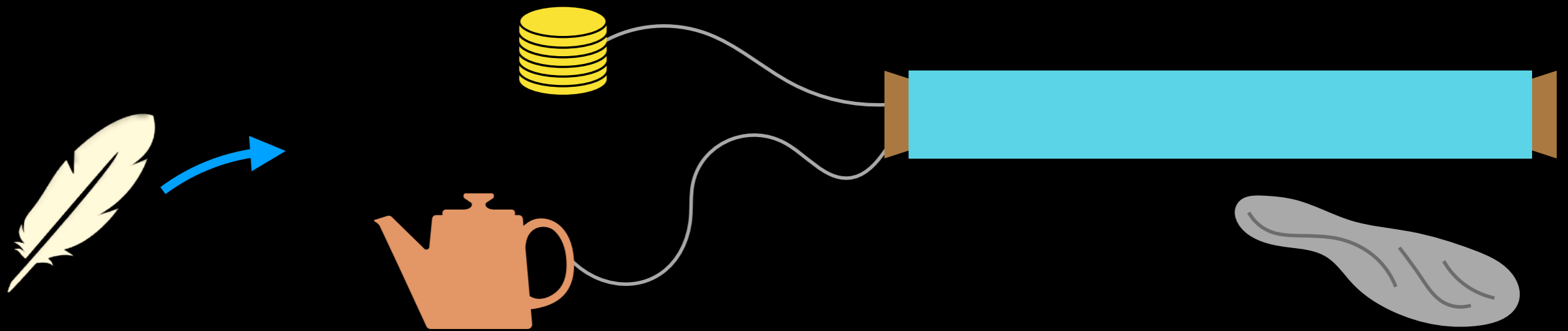
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Metals can be “electrified” by contact with other “electrified” bodies!

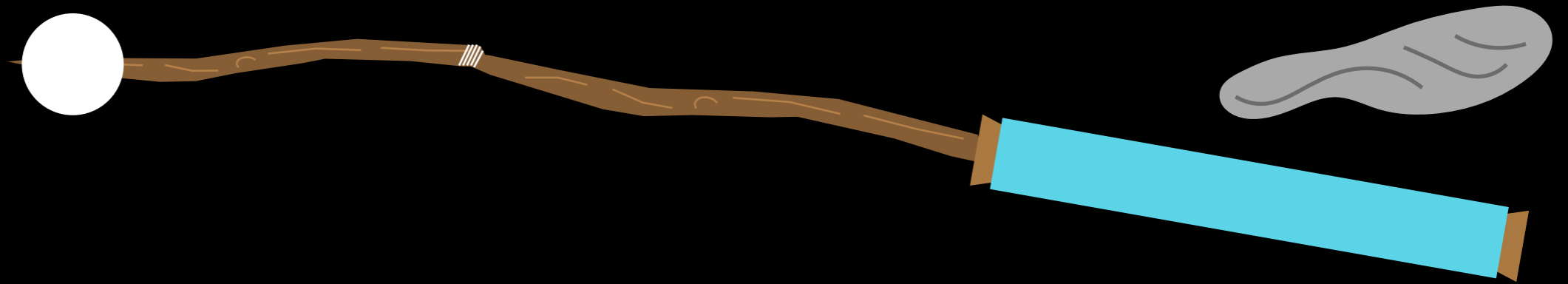
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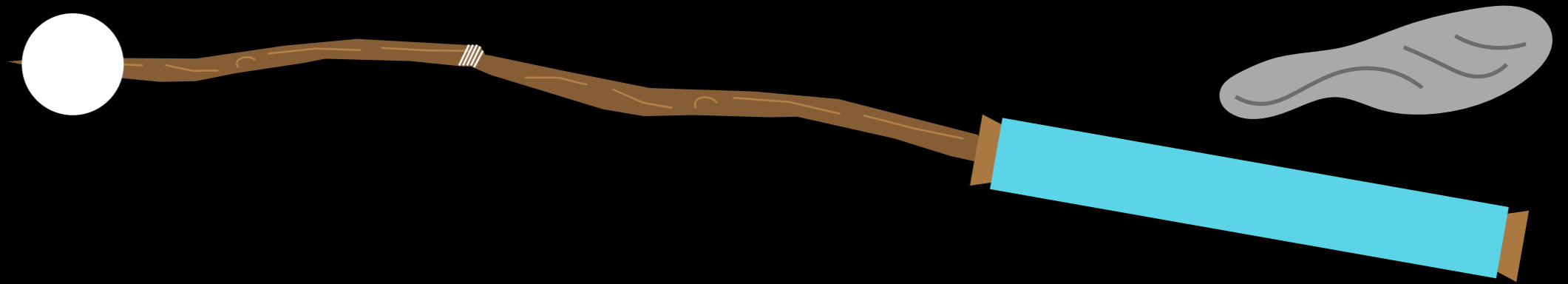
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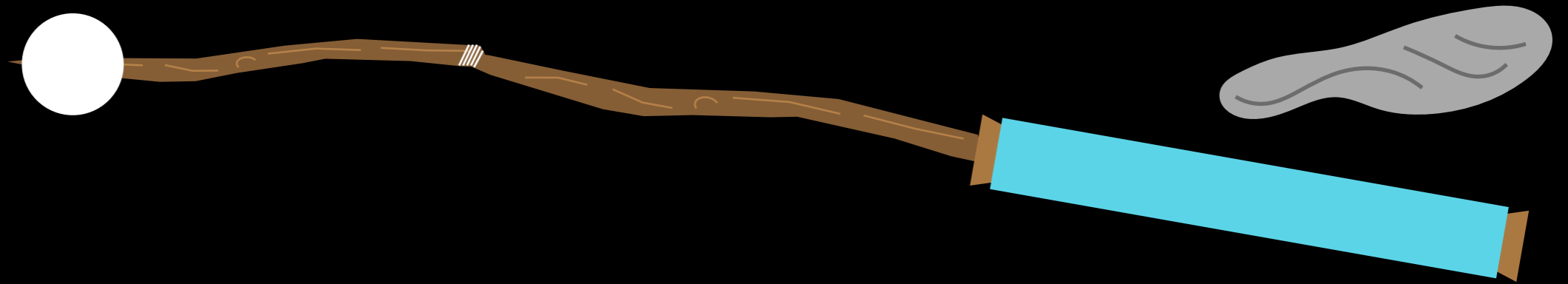
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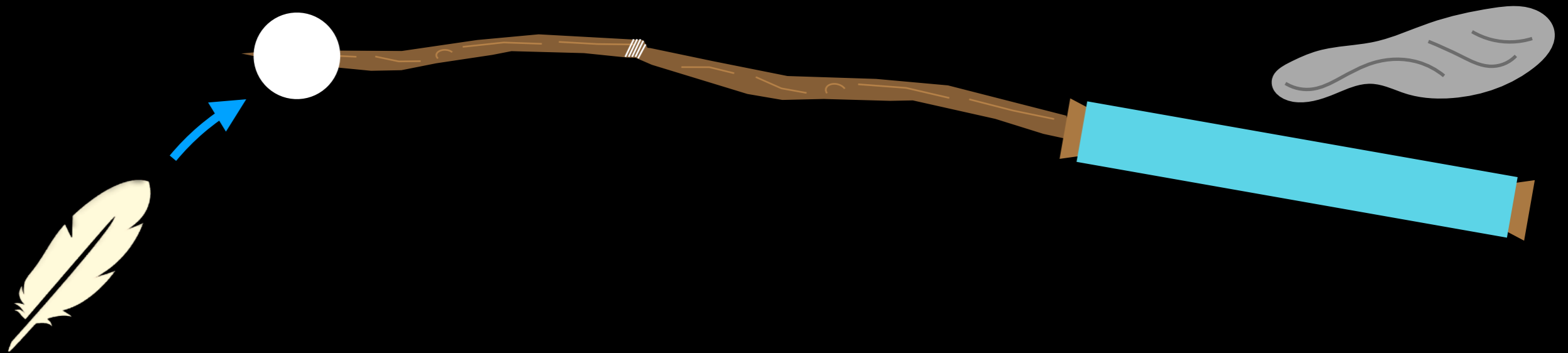


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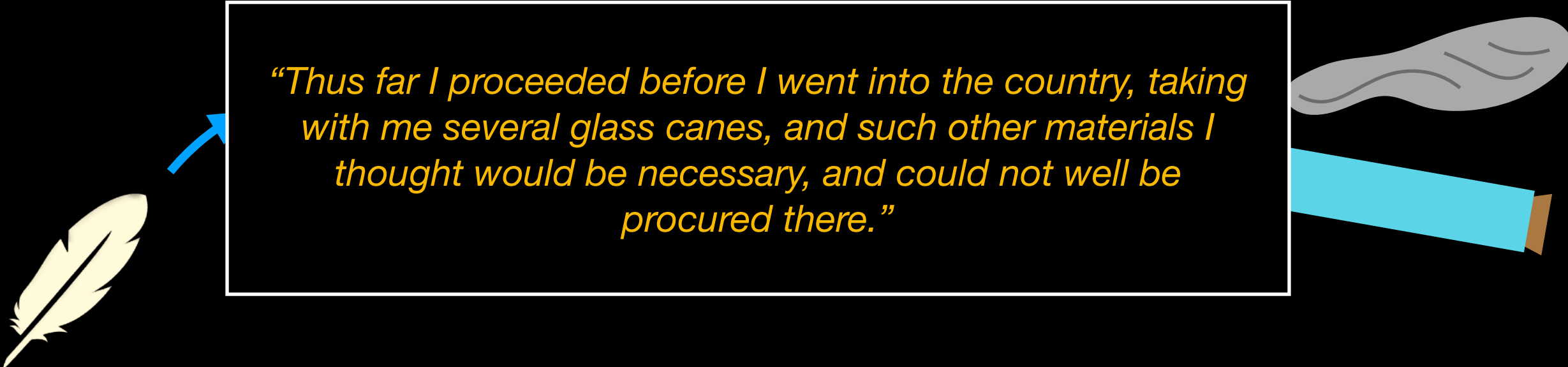


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“Thus far I proceeded before I went into the country, taking with me several glass canes, and such other materials I thought would be necessary, and could not well be procured there.”

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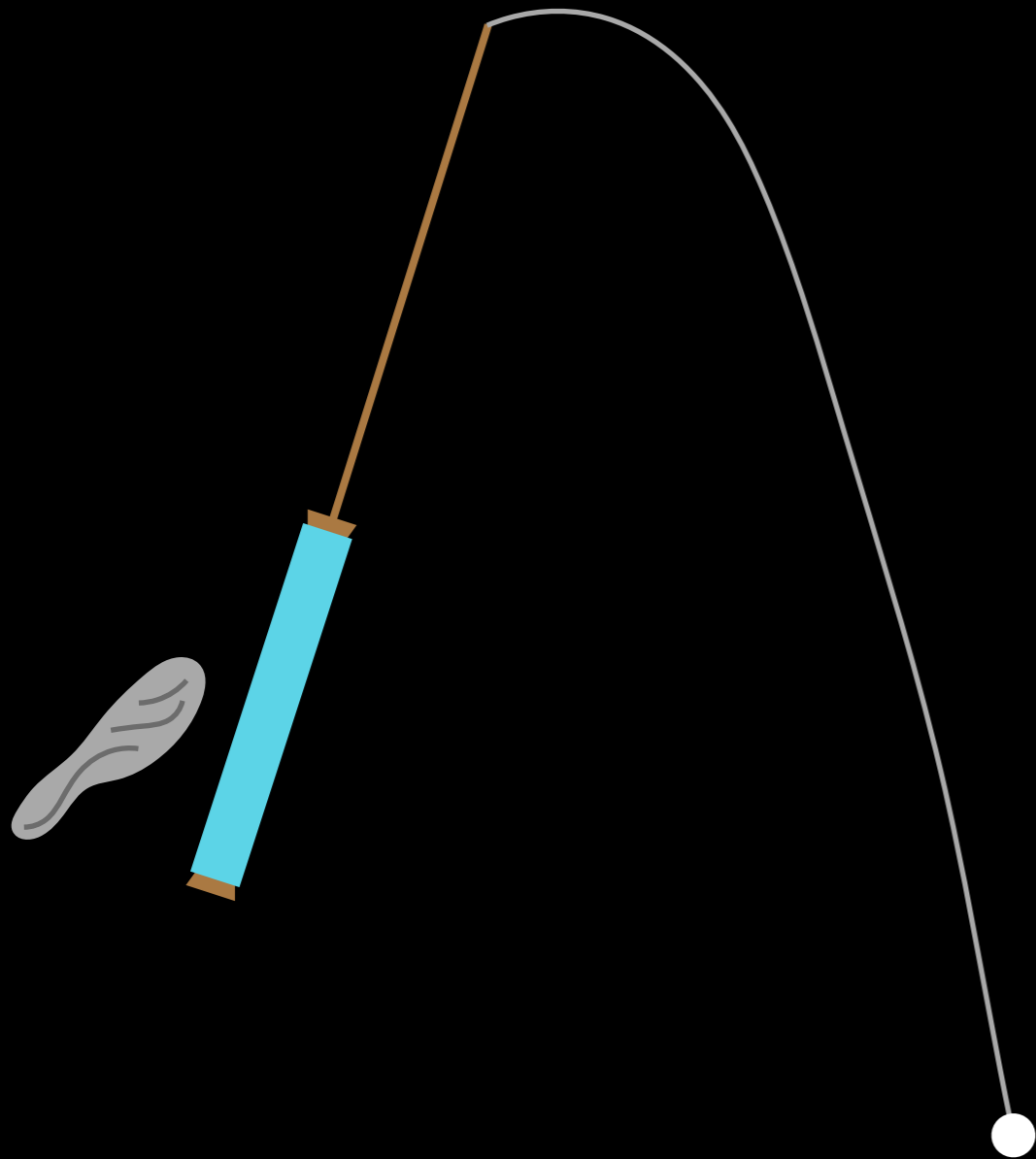
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“May 31st, in the morning: to a pole of eighteen feet there was tied a line of thirty-four feet in length; so that the pole and line together were fifty-two feet.”

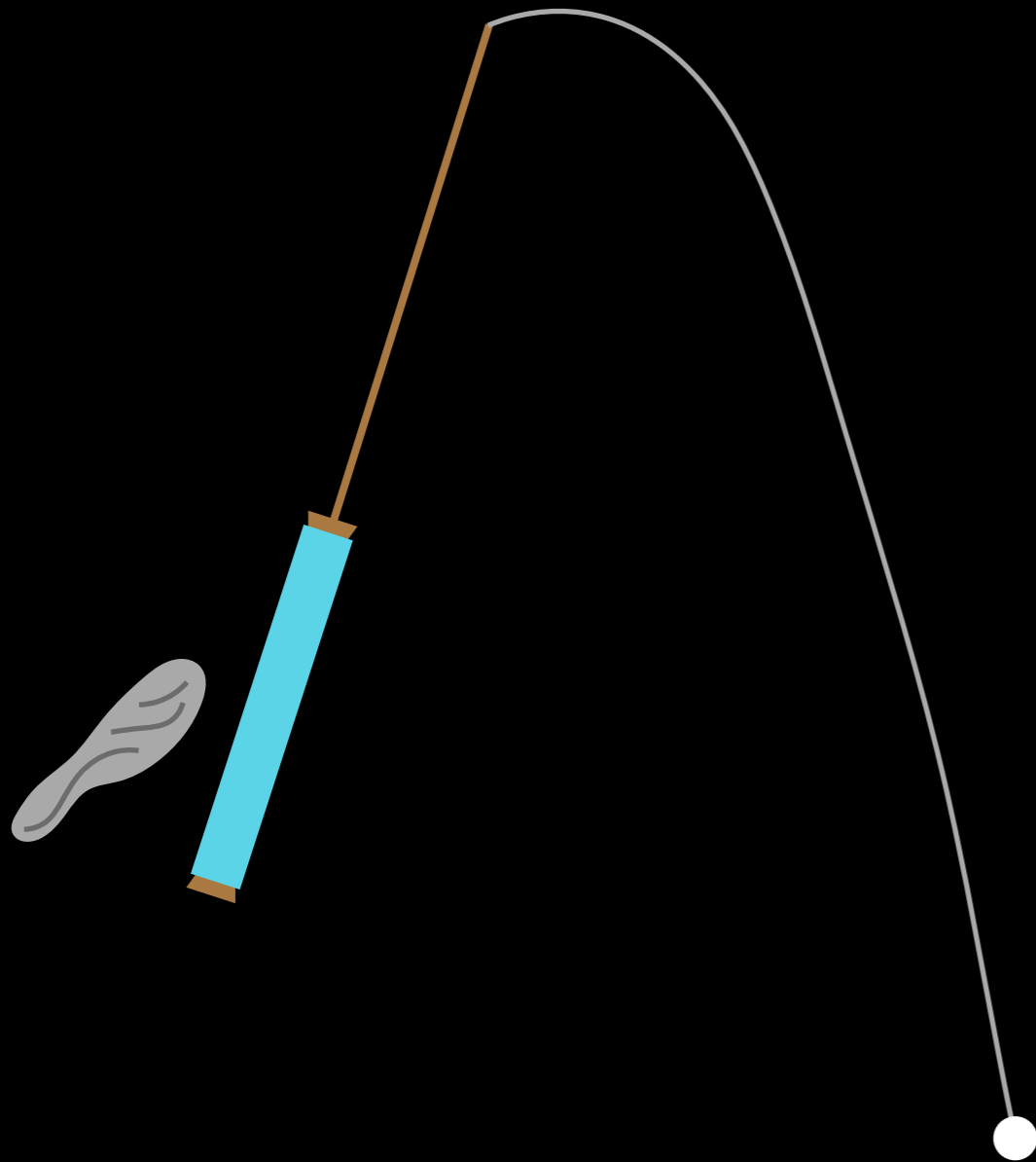
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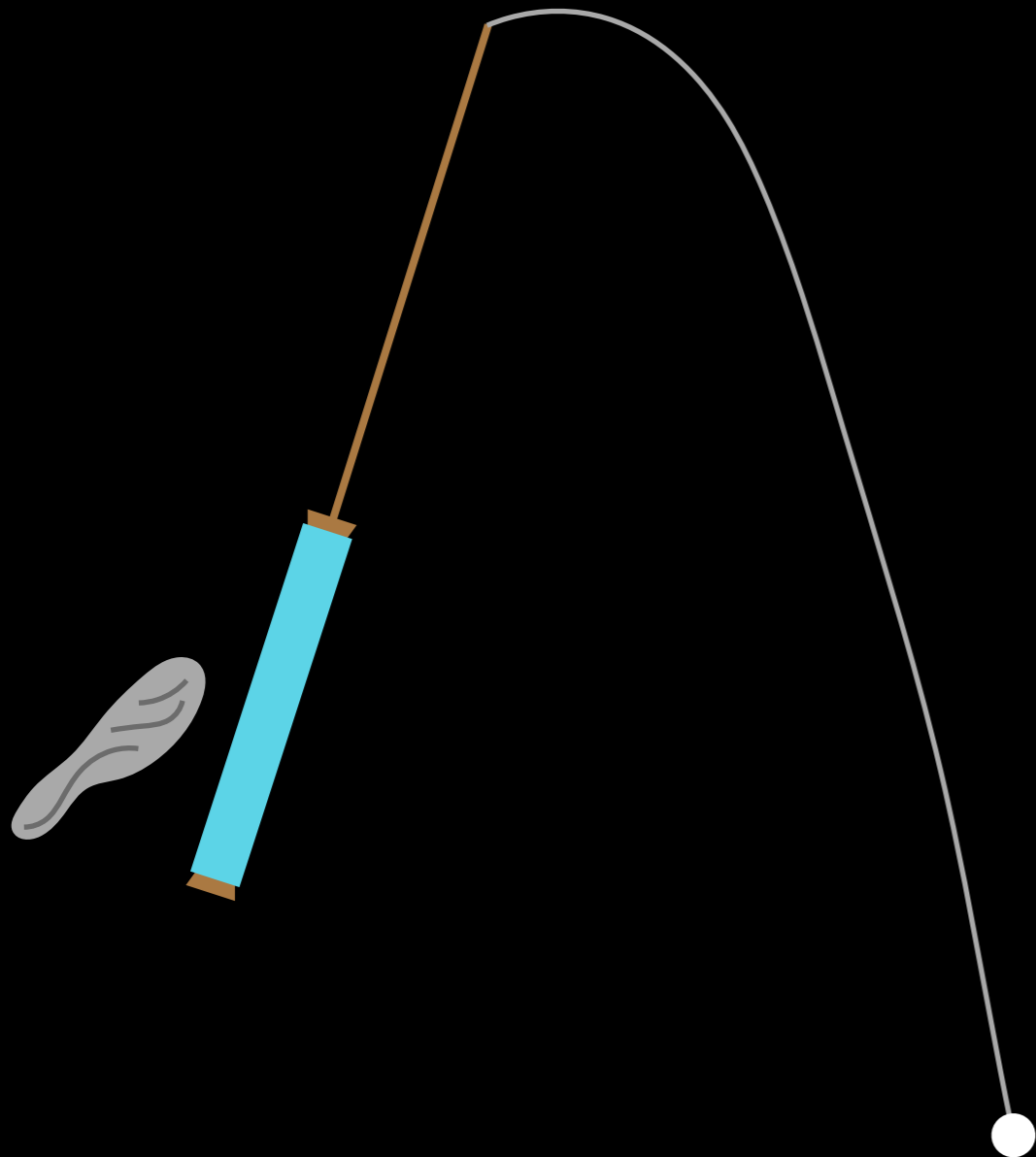
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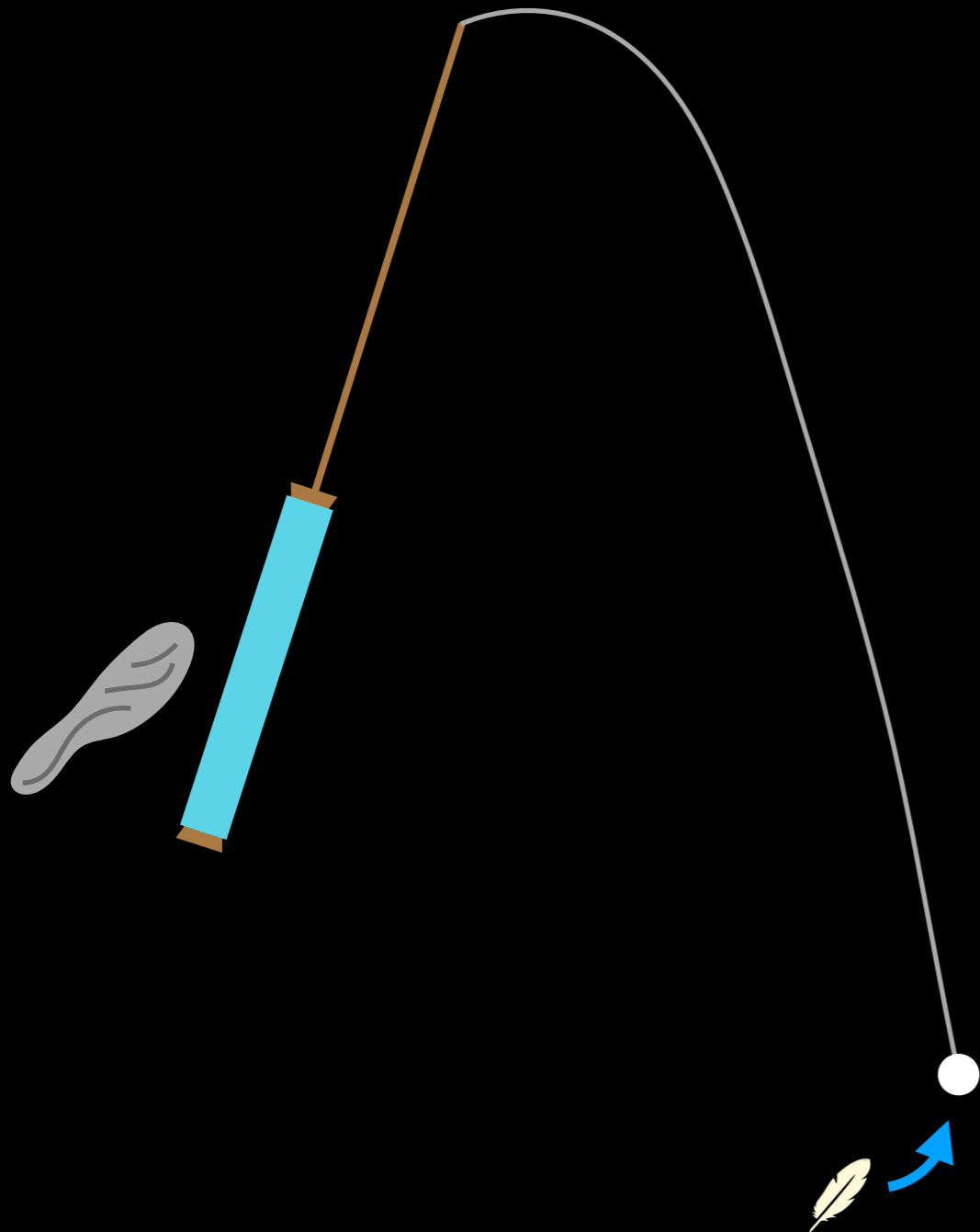


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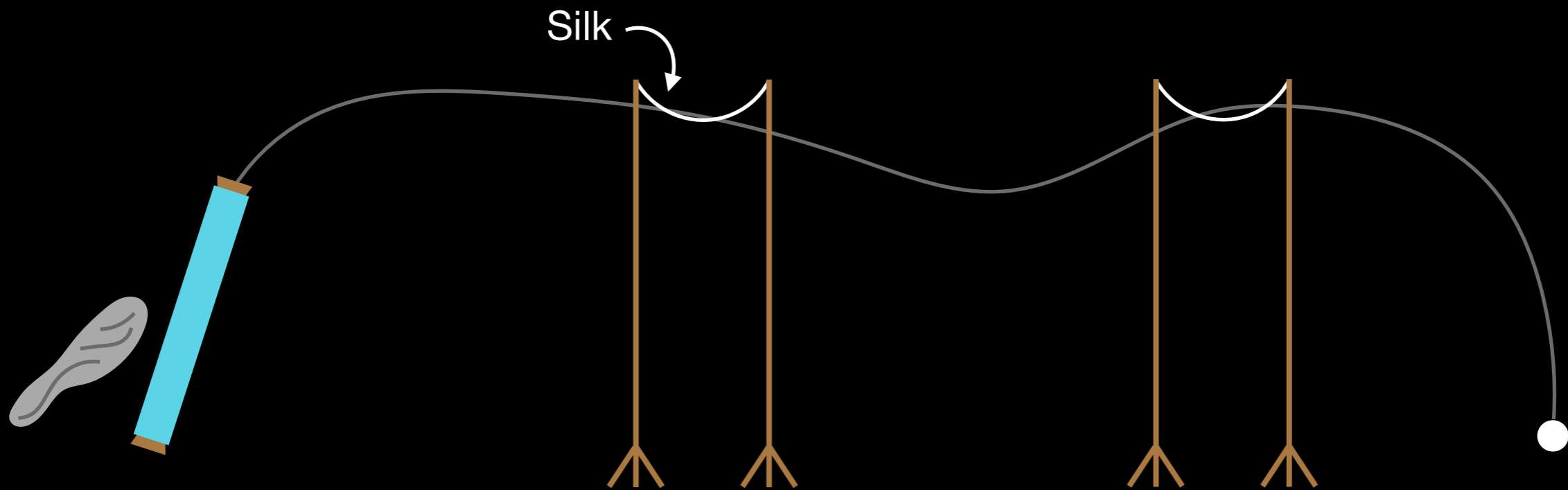
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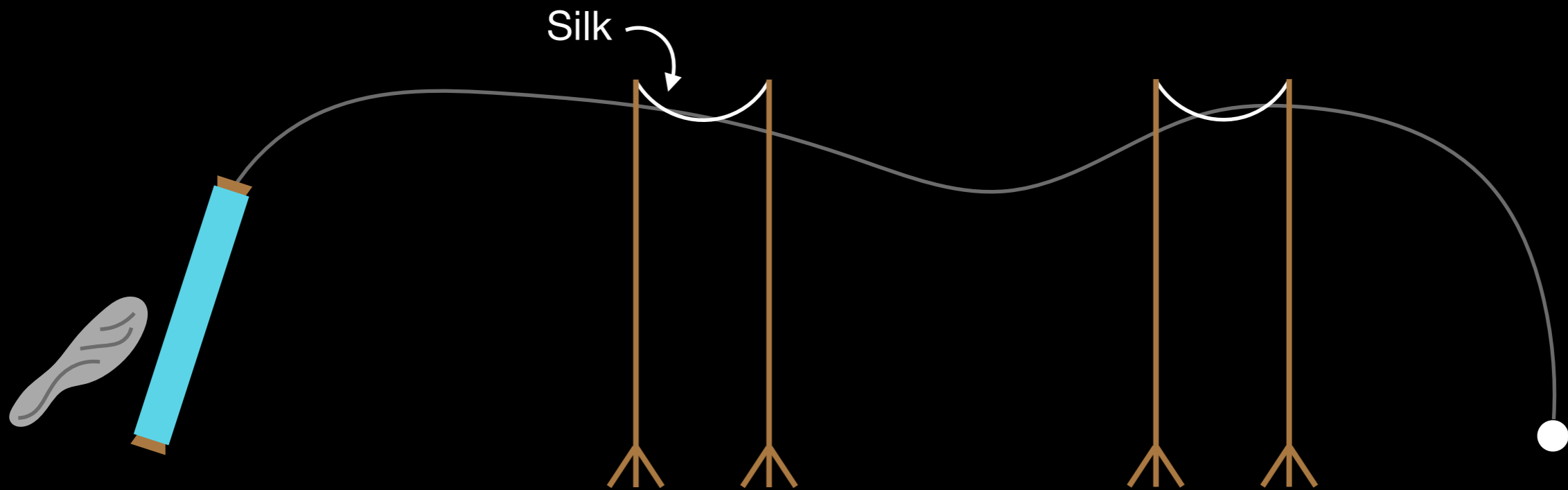
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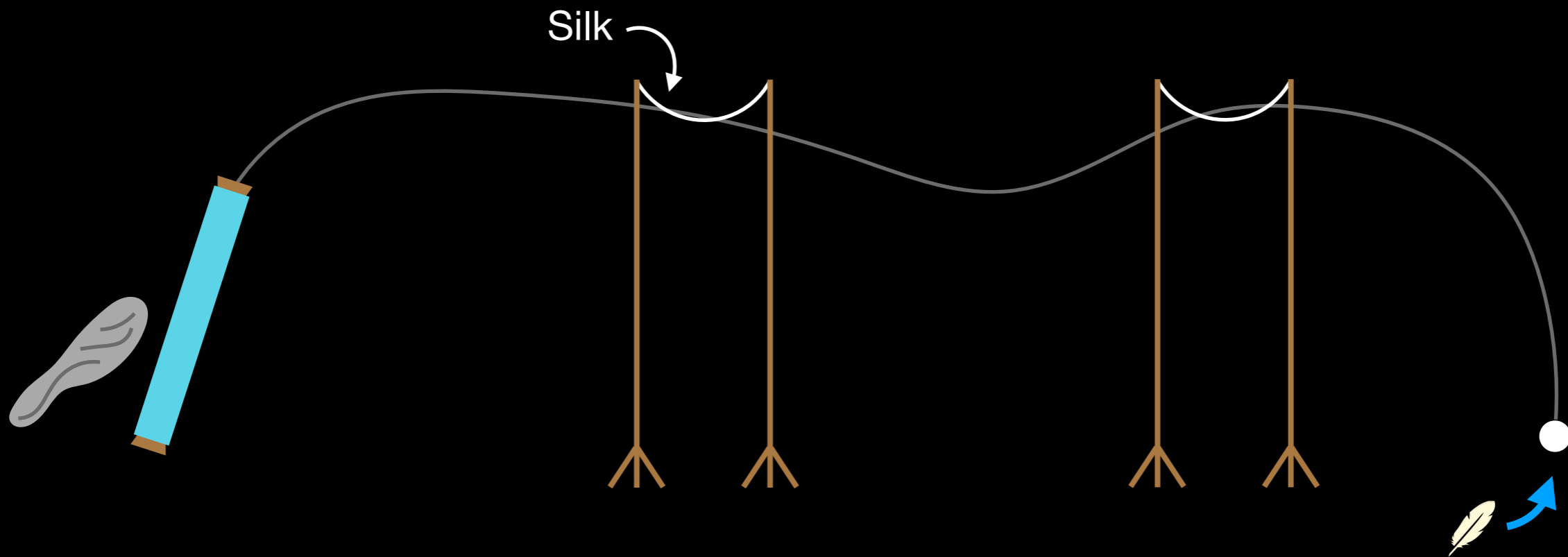
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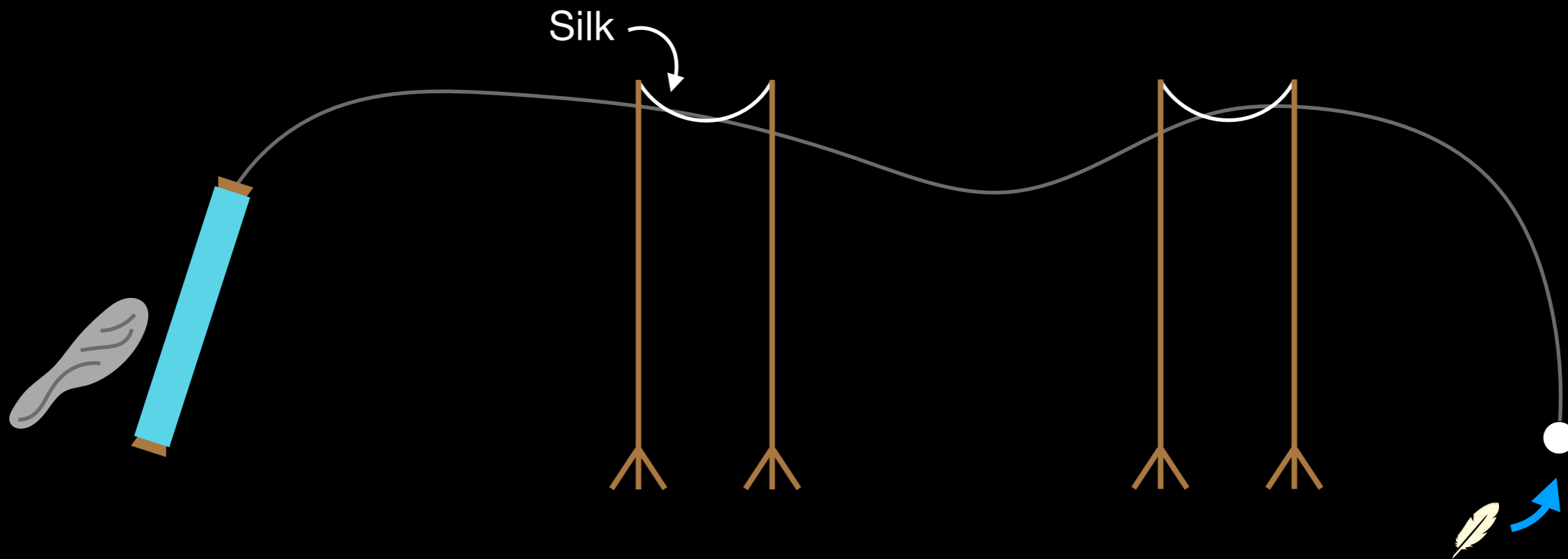
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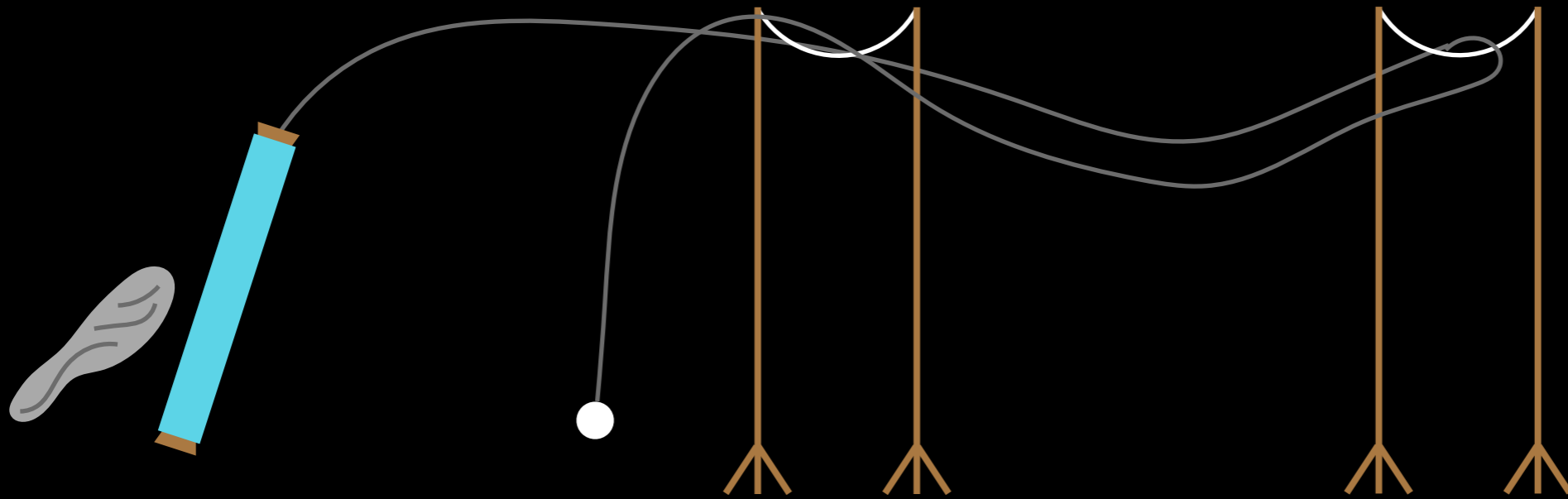
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Does the thin silk line hinder the flow of “Electrick Verture”?



Horizontal transmission

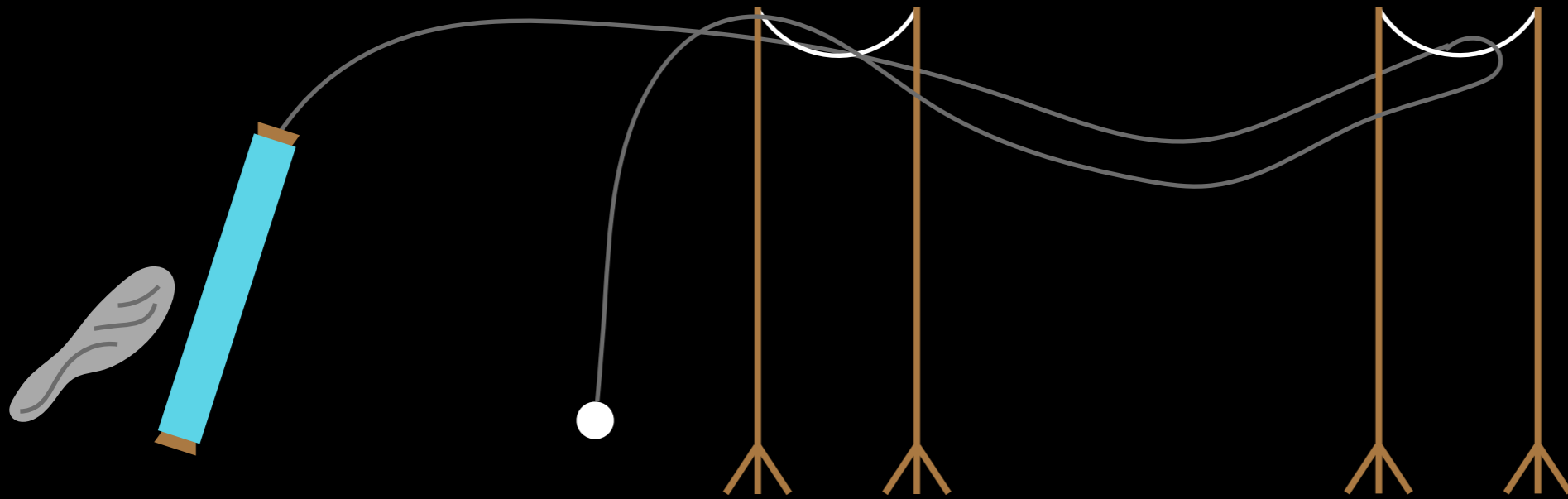
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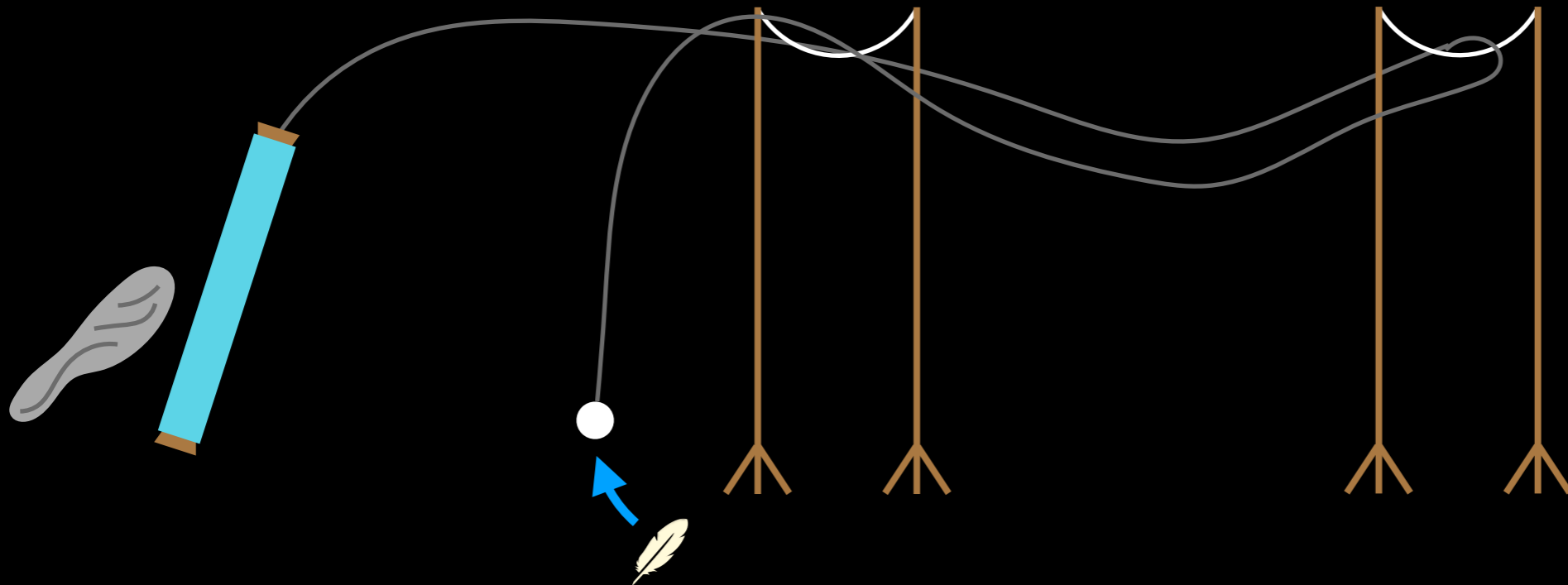
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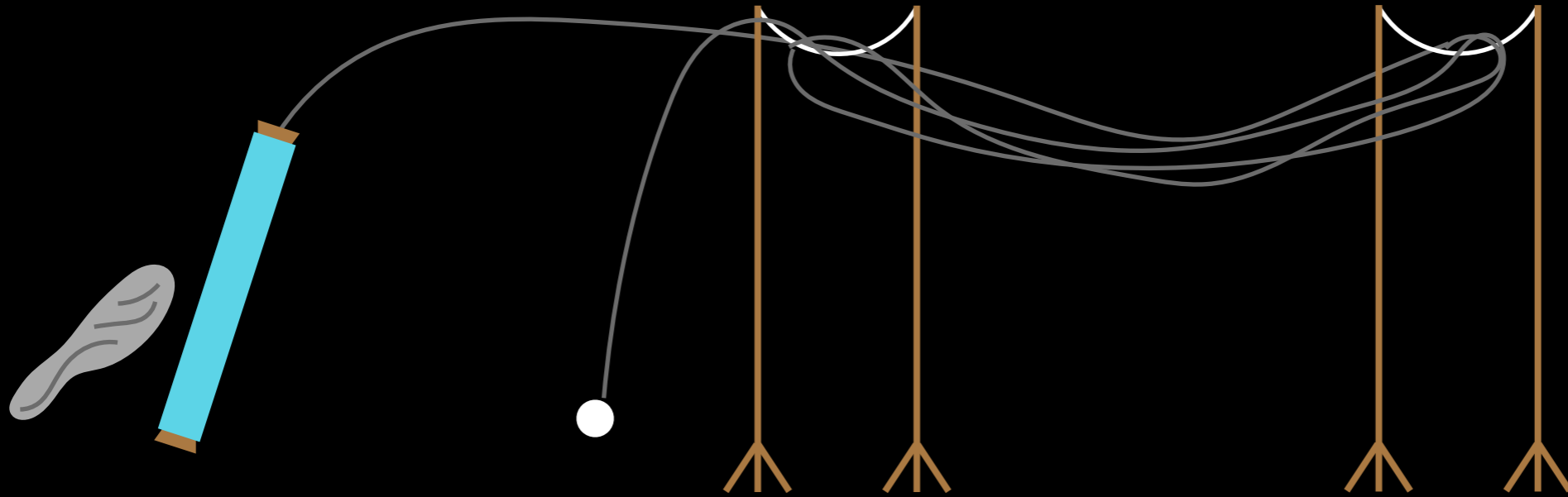
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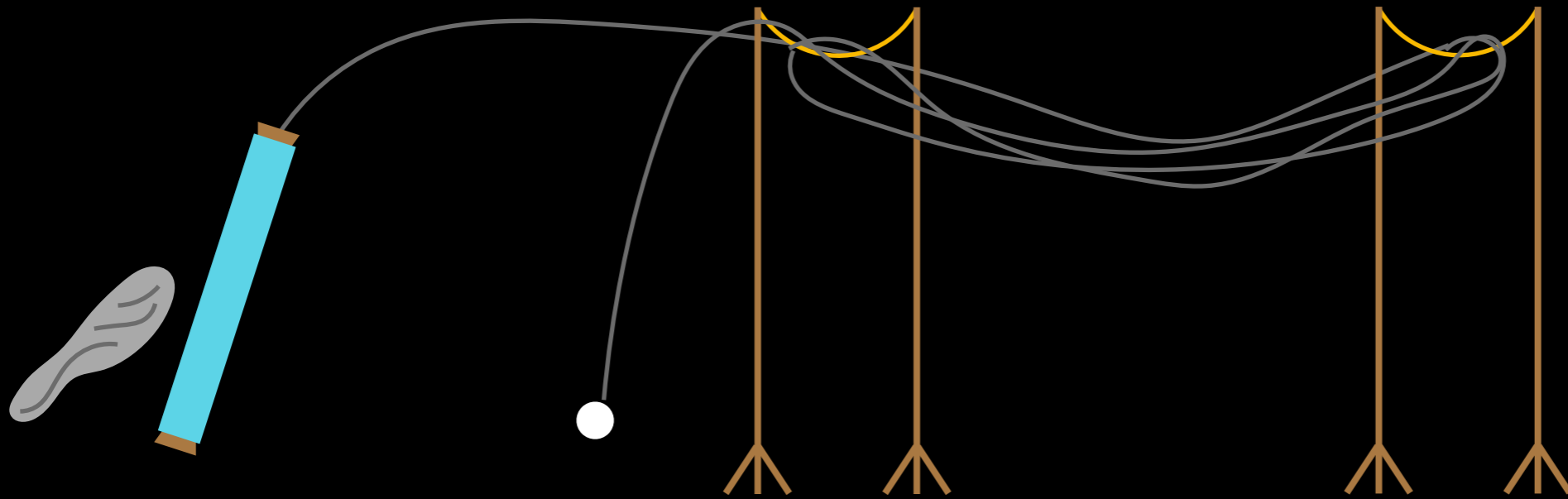
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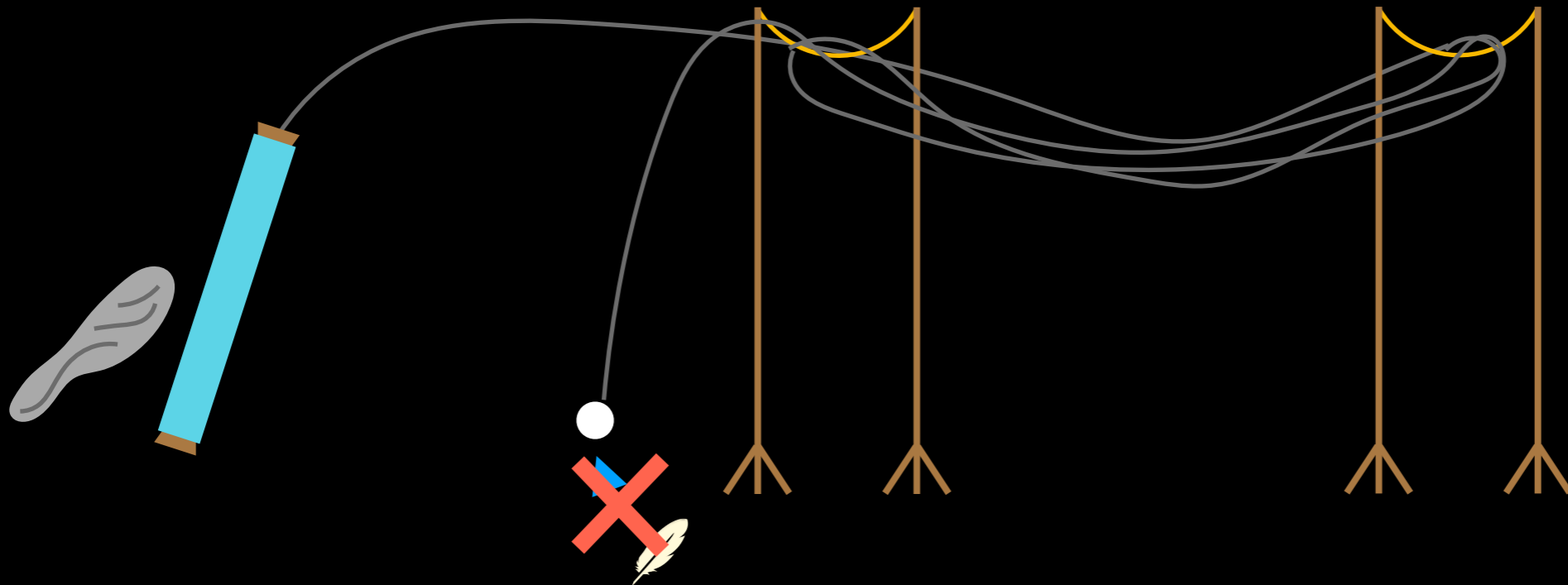
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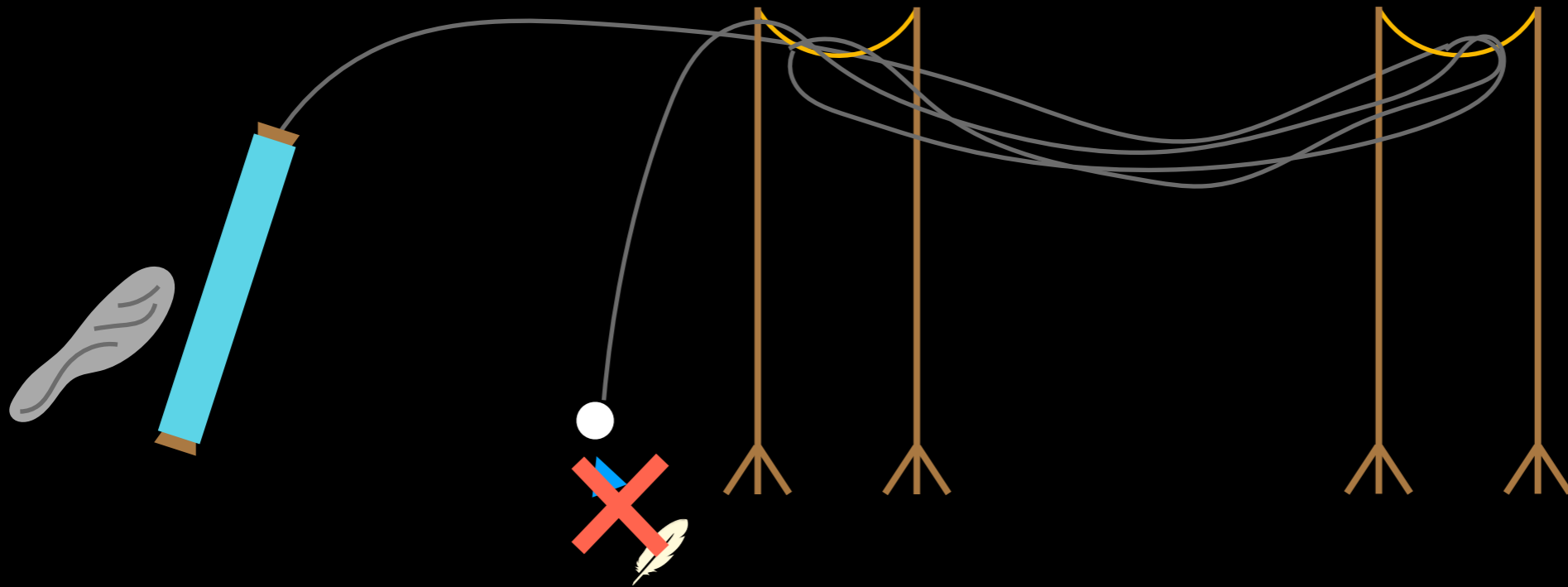
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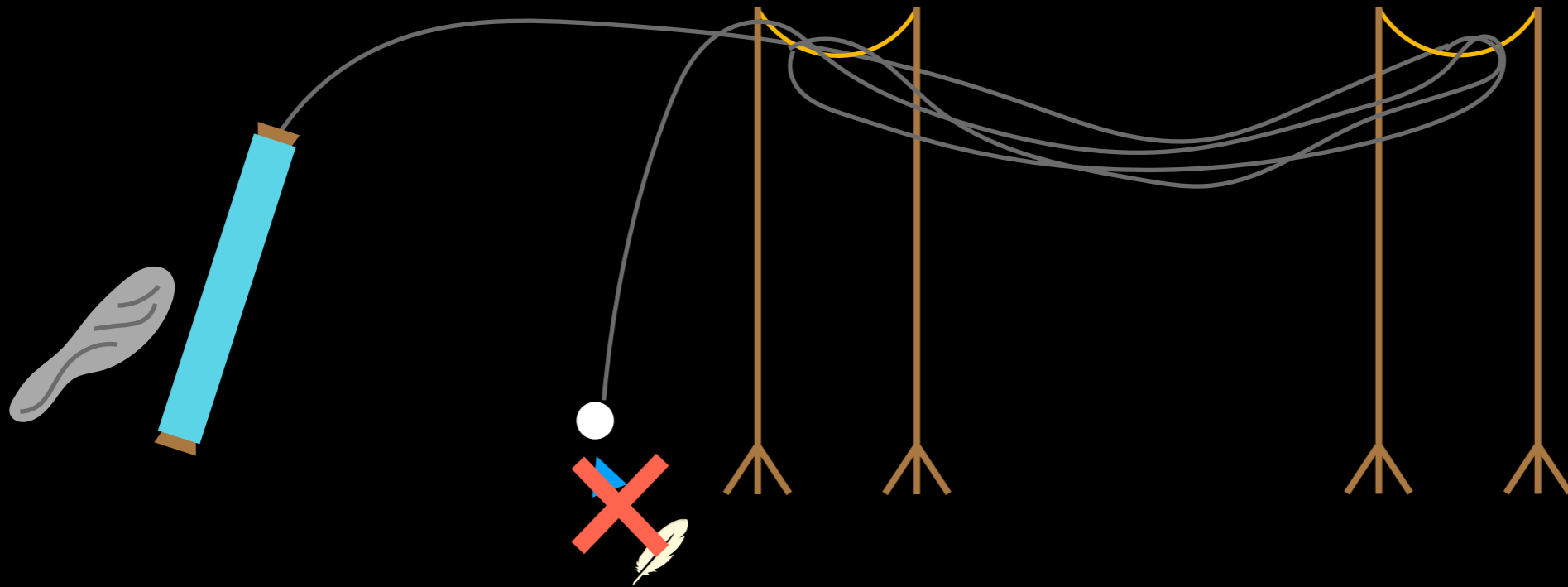


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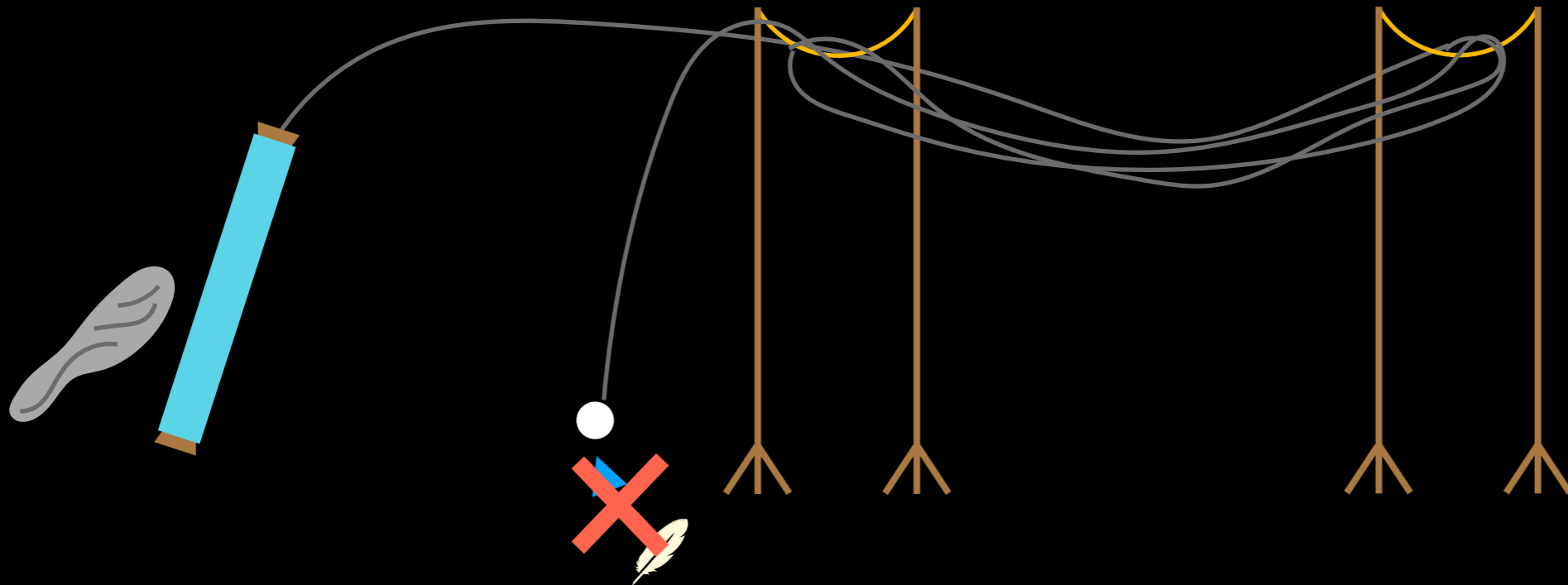
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The crucial discovery

“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.”

“When the Effluvia come to the wire 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.”



The crucial discovery

*“By which
lines that s*

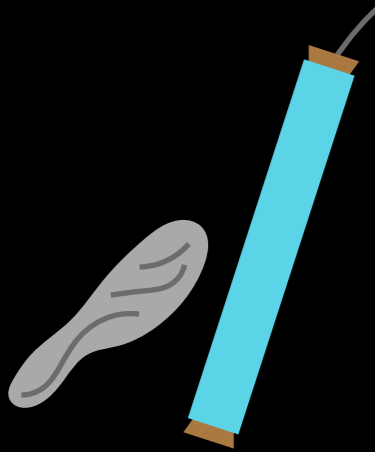
*“When the
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**Bodies “communicate” electricity not in proportion
to their size, but according to a new material property**

Today: “conductivity”

*upon the
ng small,*

*the timber,
that is to*



The crucial discovery

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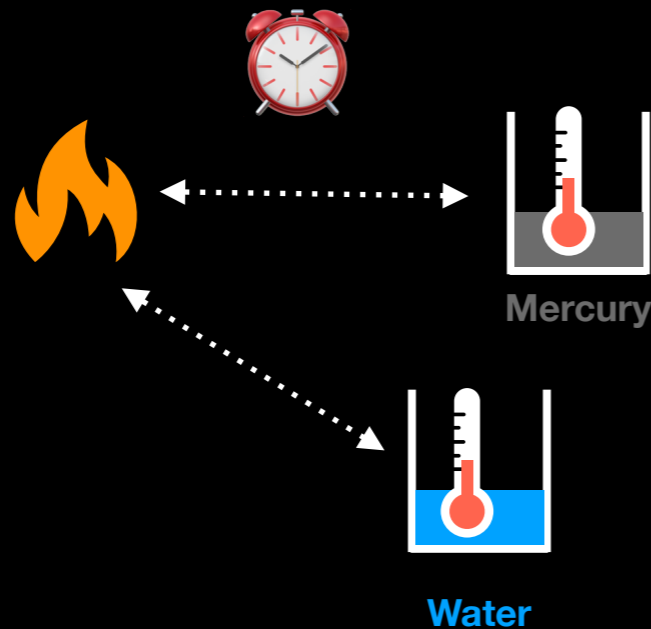
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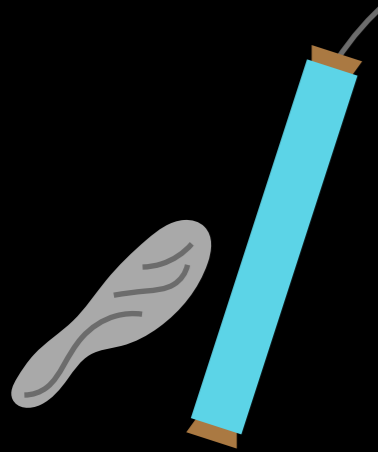
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Bodies “communicate” electricity not in proportion to their size, but according to a new material property

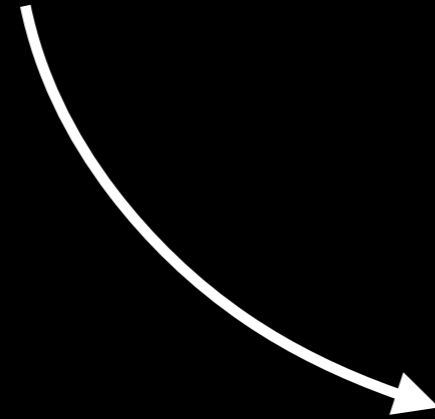
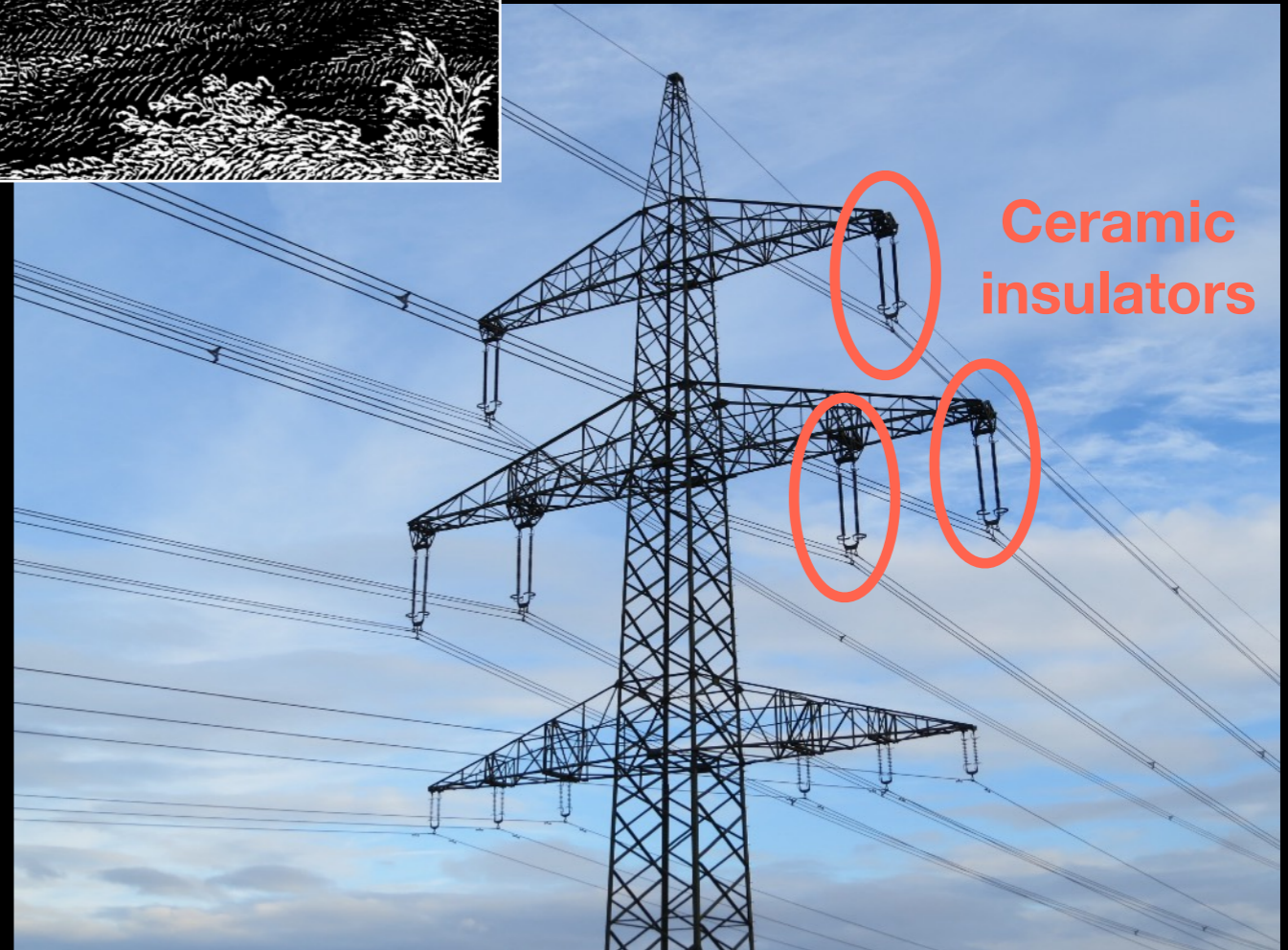
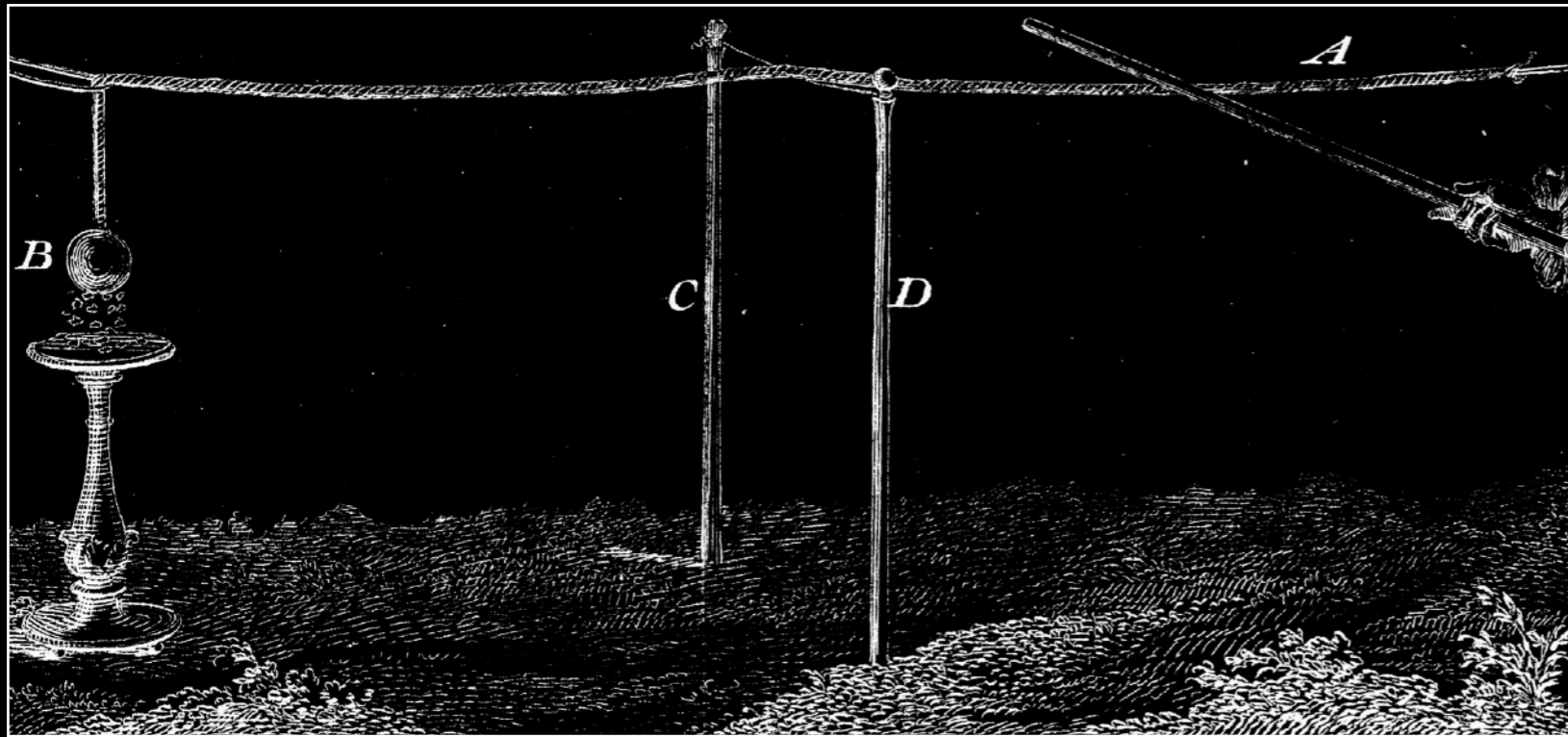
Today: “conductivity”



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

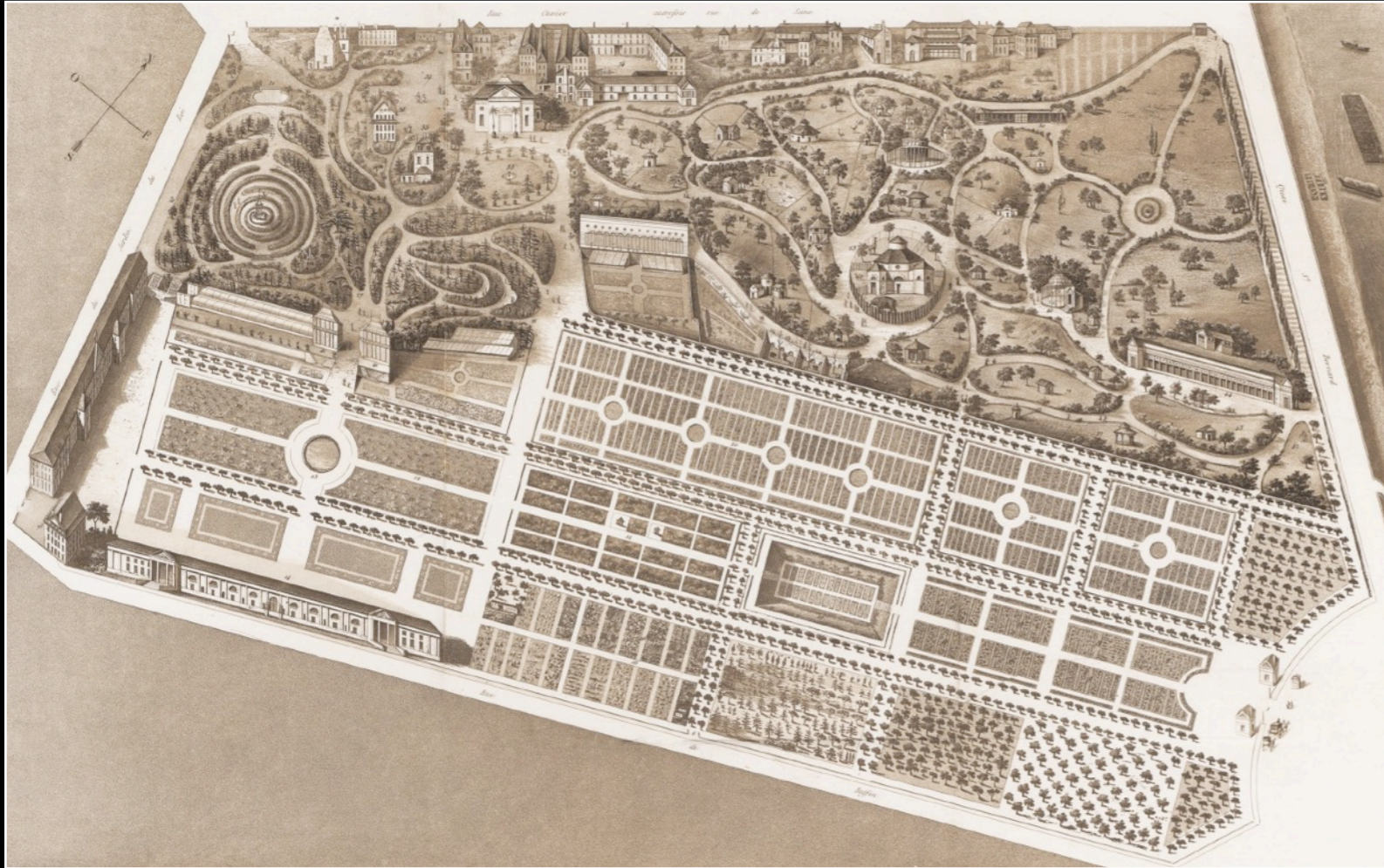


Transmission lines then and now



Charles du Fay

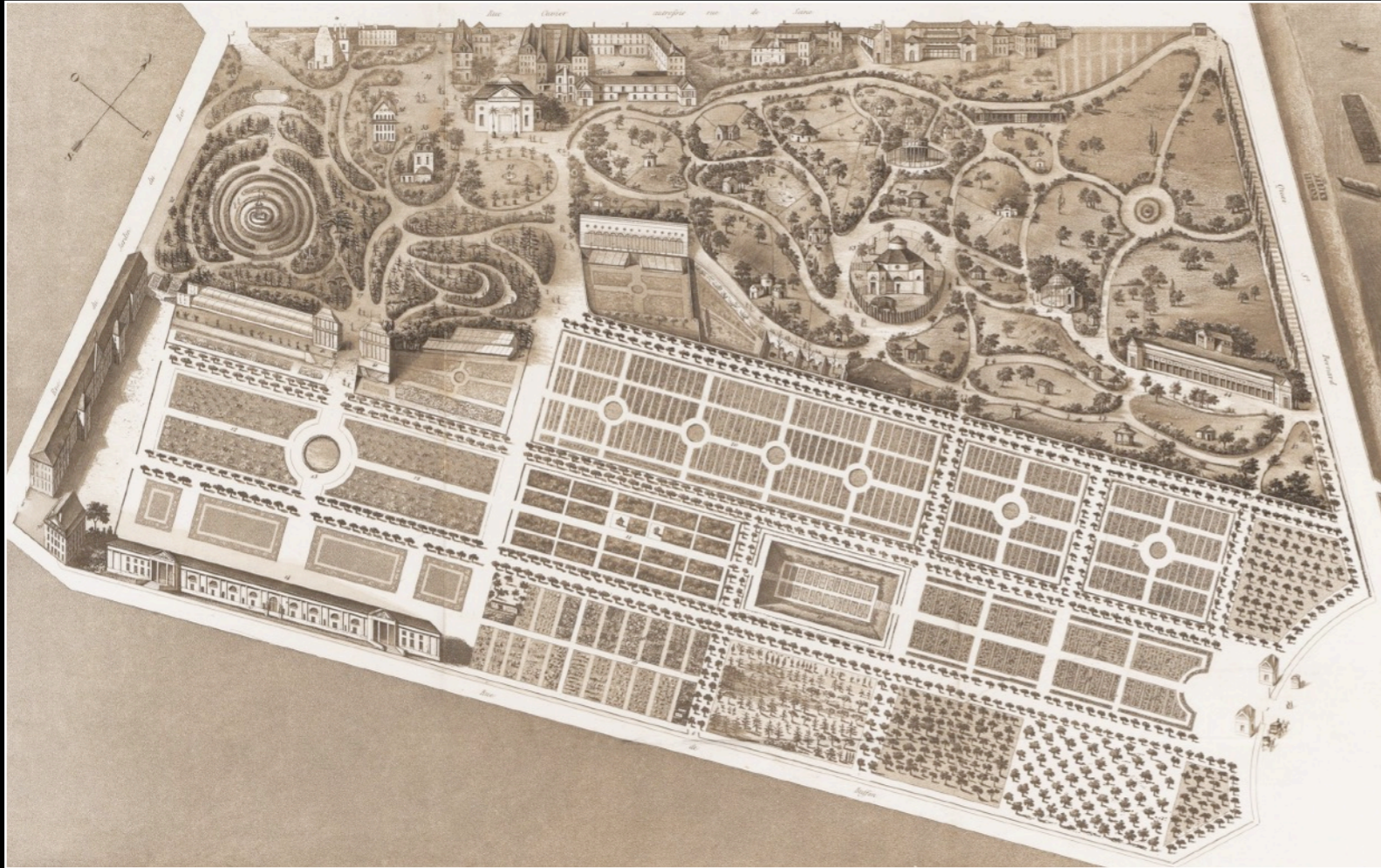
Lieutenant, gardener, academician



“Jardin du Roi”

Charles du Fay

Lieutenant, gardener, academician



“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 displeas'd 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.”

A rigorous experimental programme

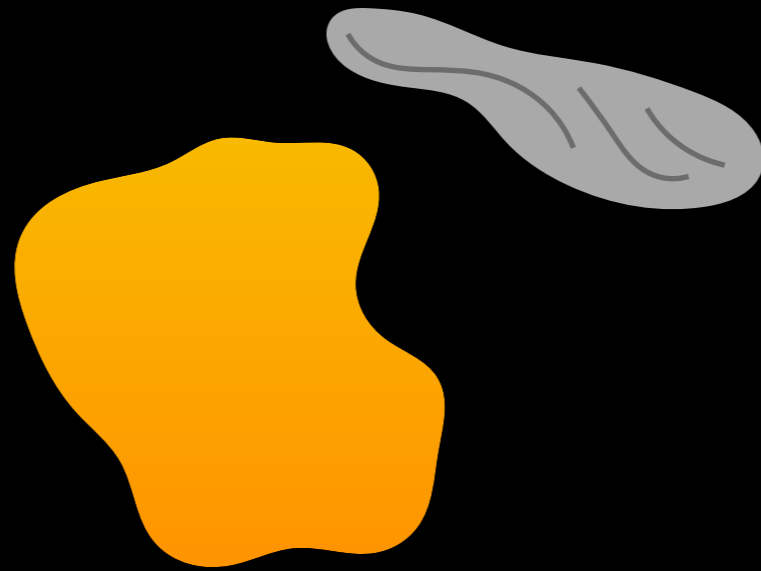
“I discovered a very simple principle.”

“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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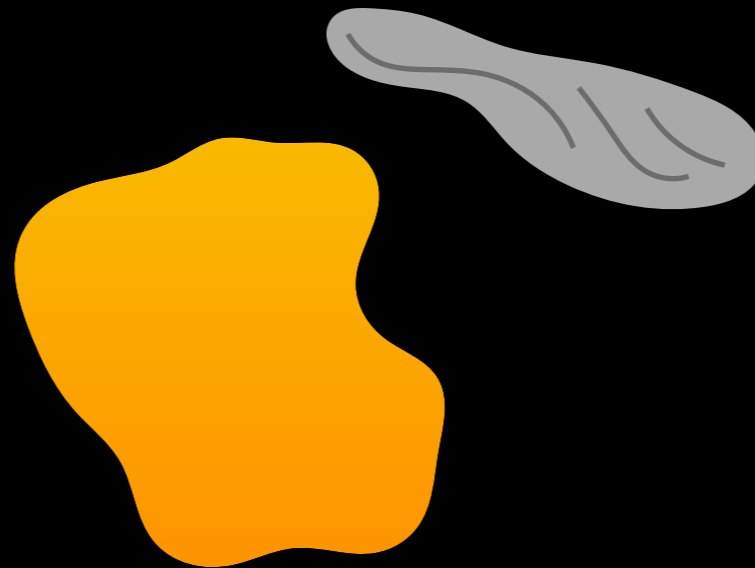


A rigorous experimental programme

“I discovered a very simple principle.”

“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.”

“... all kinds of stones, as well precious as common, all sorts of wood ...”



A rigorous experimental programme

“I discovered a very simple principle.”

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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
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“One would try in vain using a platform made of wood or metal.”



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“One would try in vain using a platform made of wood or metal.”



“Du Fay’s rule”

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“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.”



Two kinds of electricity?!

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“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 ...”

Two kinds of electricity?!

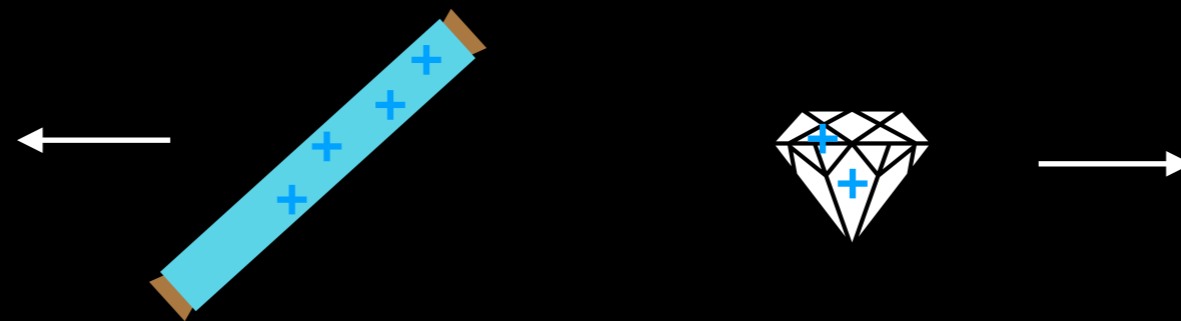
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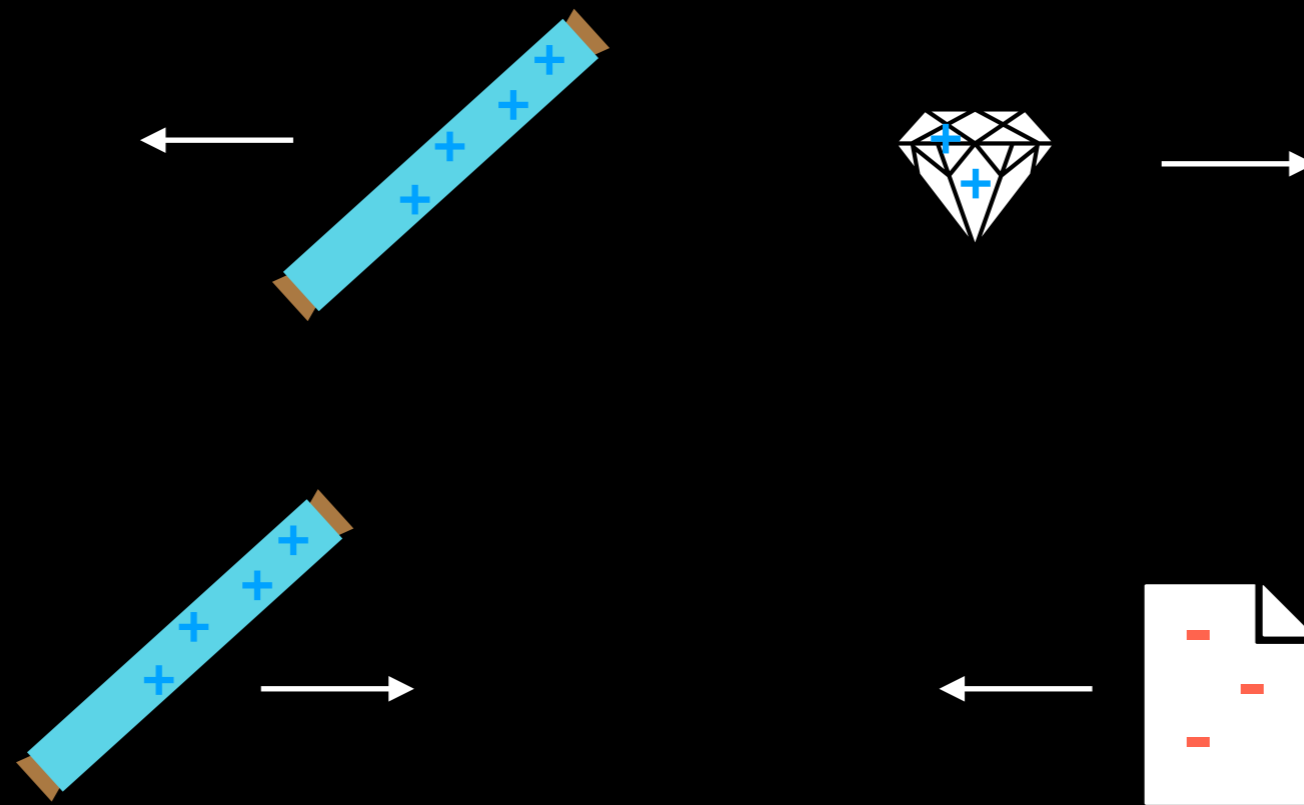
“... and on the contrary, attracts all those of the resinous electricity.”



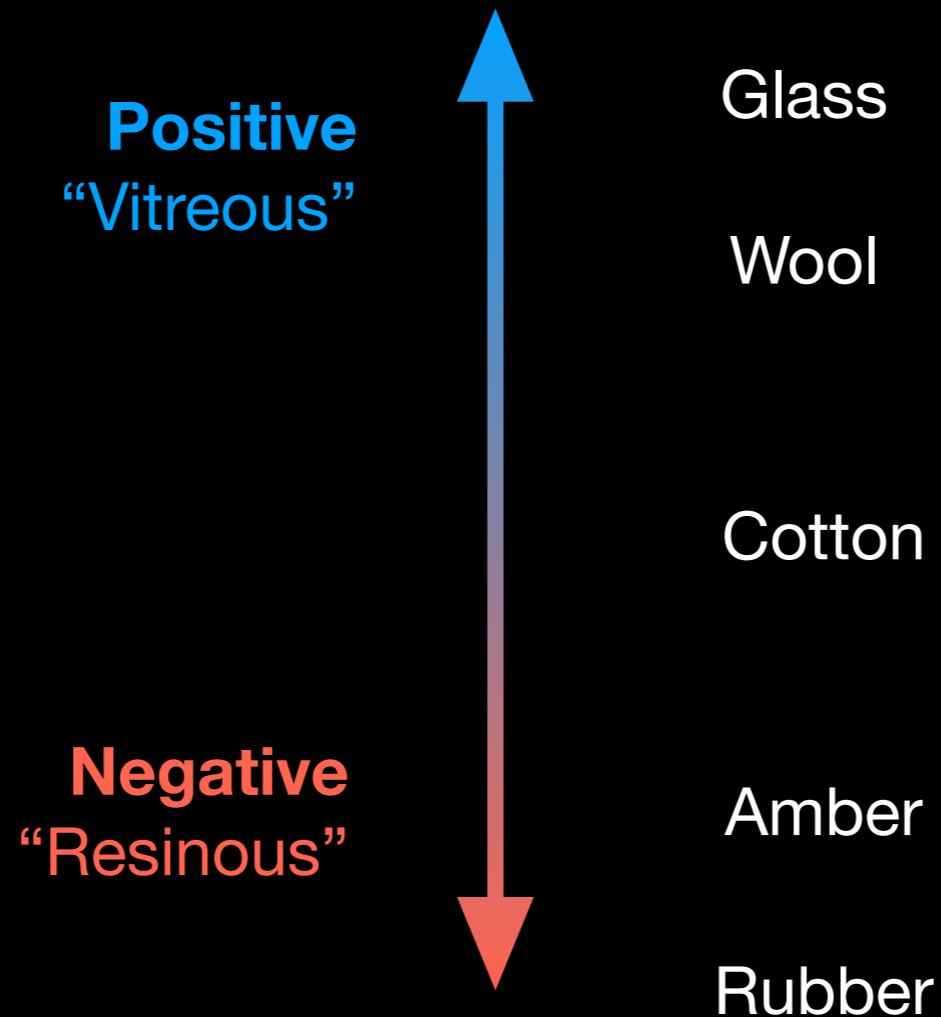
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Today: the tribo-electric series

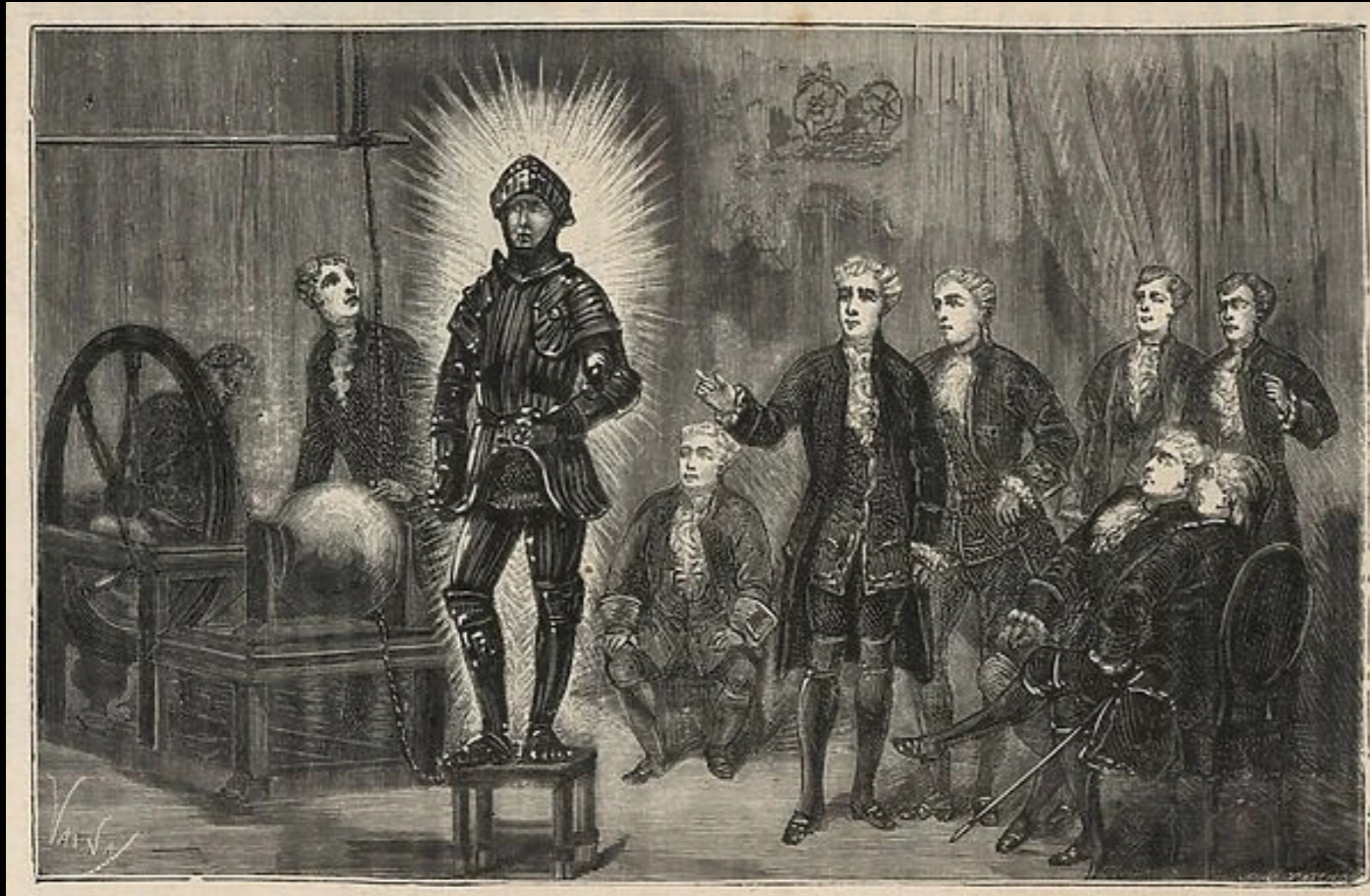


Depends both on the body that is being rubbed,
and the body that does the rubbing

Electricity as entertainment *(ca. 1740)*

Electricity as entertainment (ca. 1740)

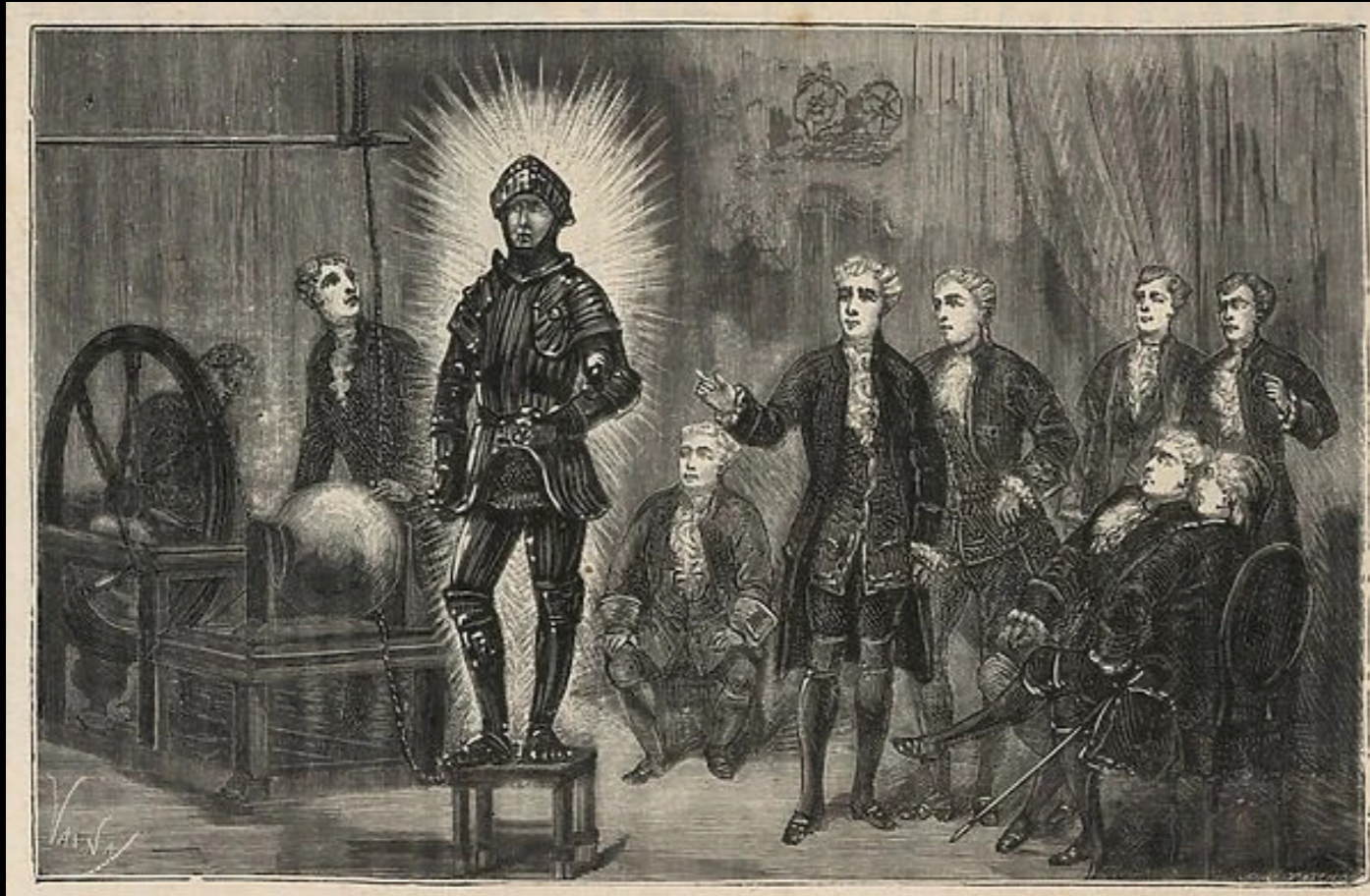
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“Beatification”

Electricity as entertainment (ca. 1740)

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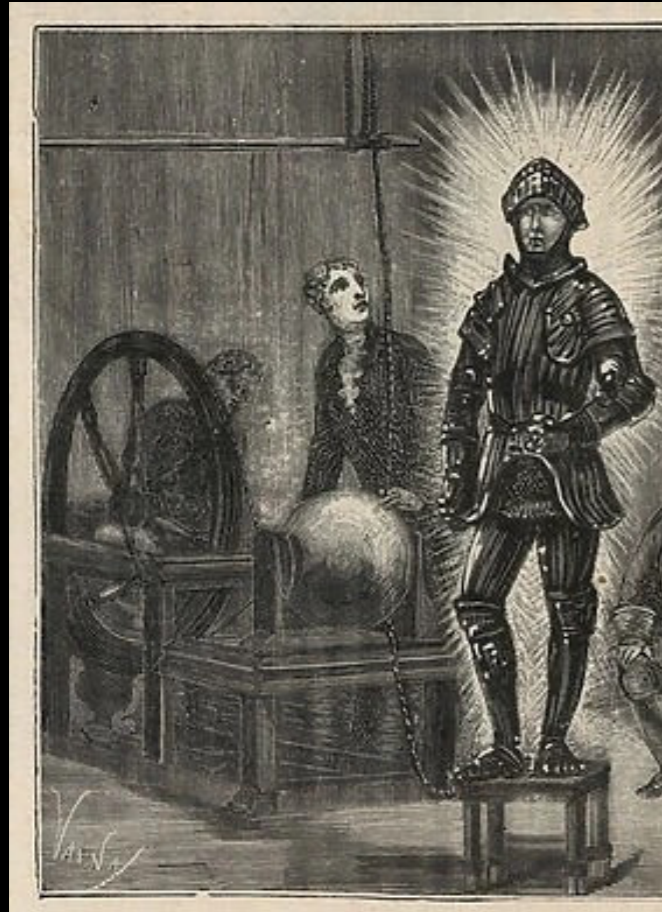


“Beatification”



“Electric kiss”

Electricity as entertainment (ca. 1740)



"Beat"



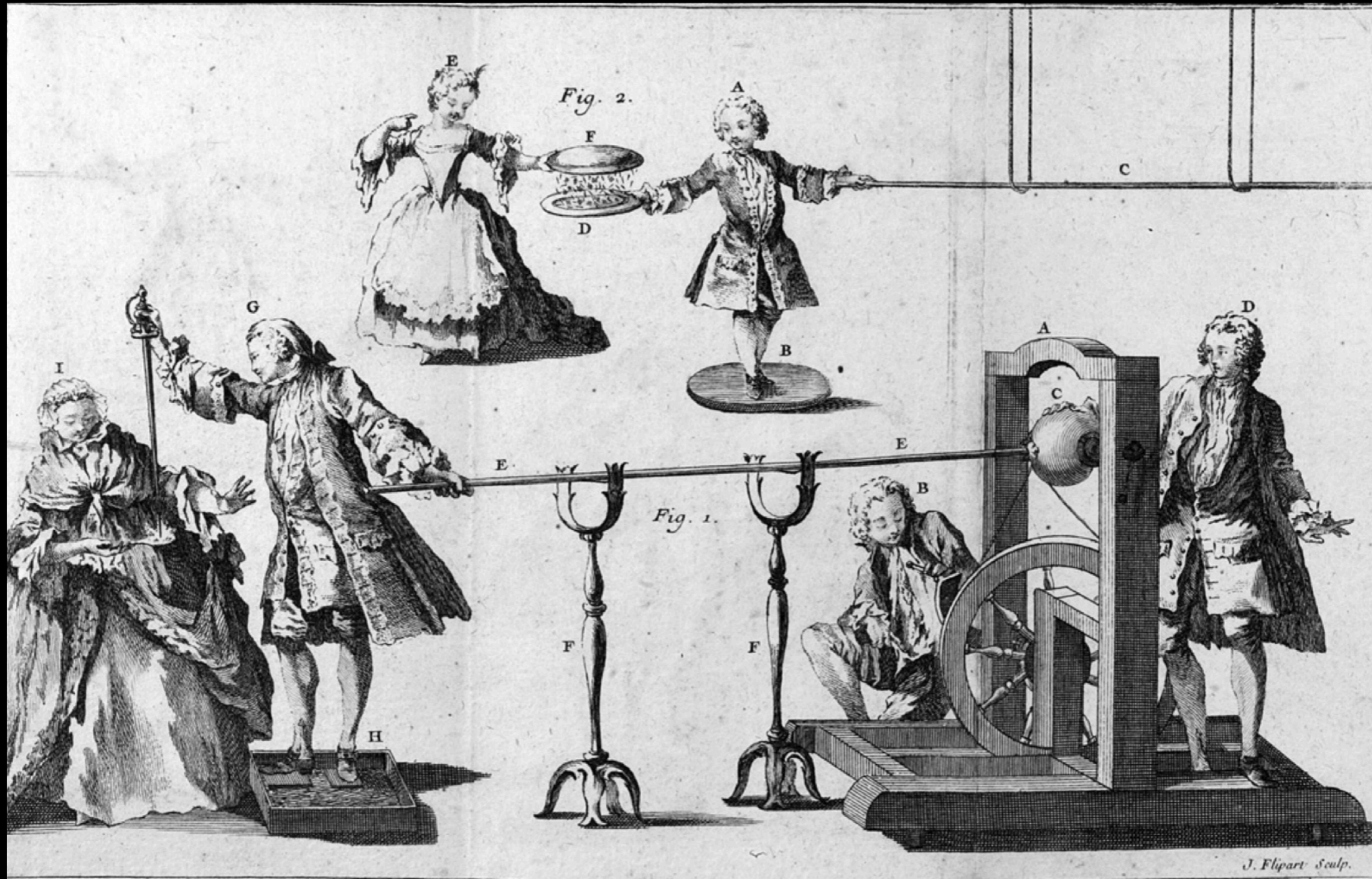
Suspended boy at Versailles



"Electric kiss"

Electricity as entertainment (ca. 1740)

Institute and Museum of the History of Science, Florence [\[link\]](#)



"Drawing fire from water"

Suspended boy at Versailles

Electricity in Prussia: Ewald von Kleist

Cleric, judge



Electricity in Prussia: Ewald von Kleist

Cleric, judge



Kamień Pomorski

Electricity in Prussia: Ewald von Kleist

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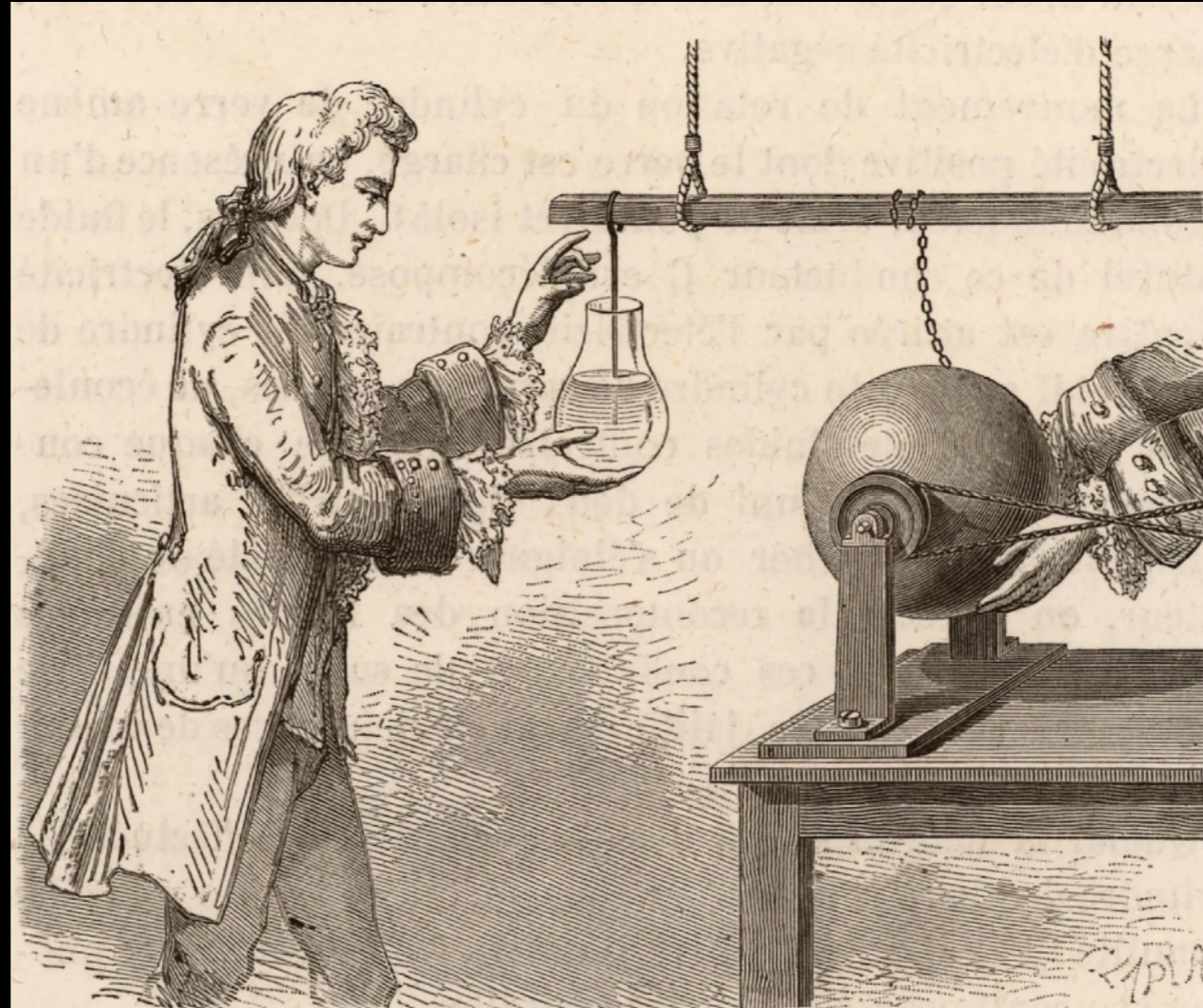
Kamień Pomorski



University of Leyden

A portable “sparking machine”

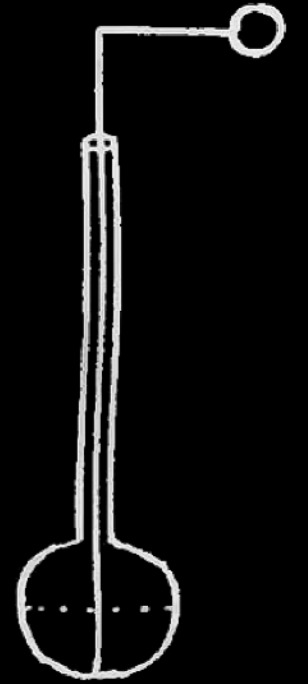
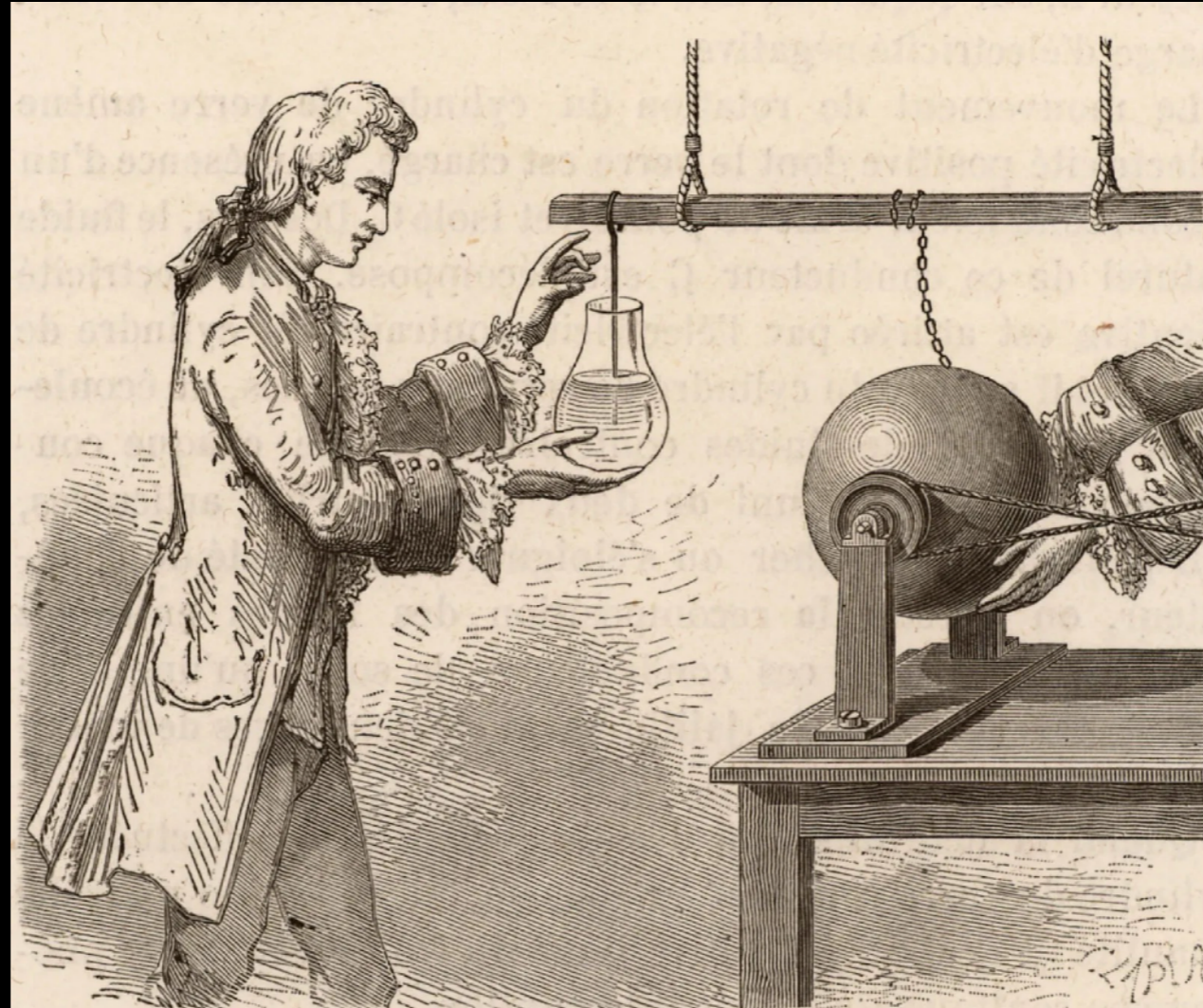
A portable “sparking machine”



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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Sent word to five confidants:

J. N. Lieberkühn from Berlin: "*novel and remarkable*"

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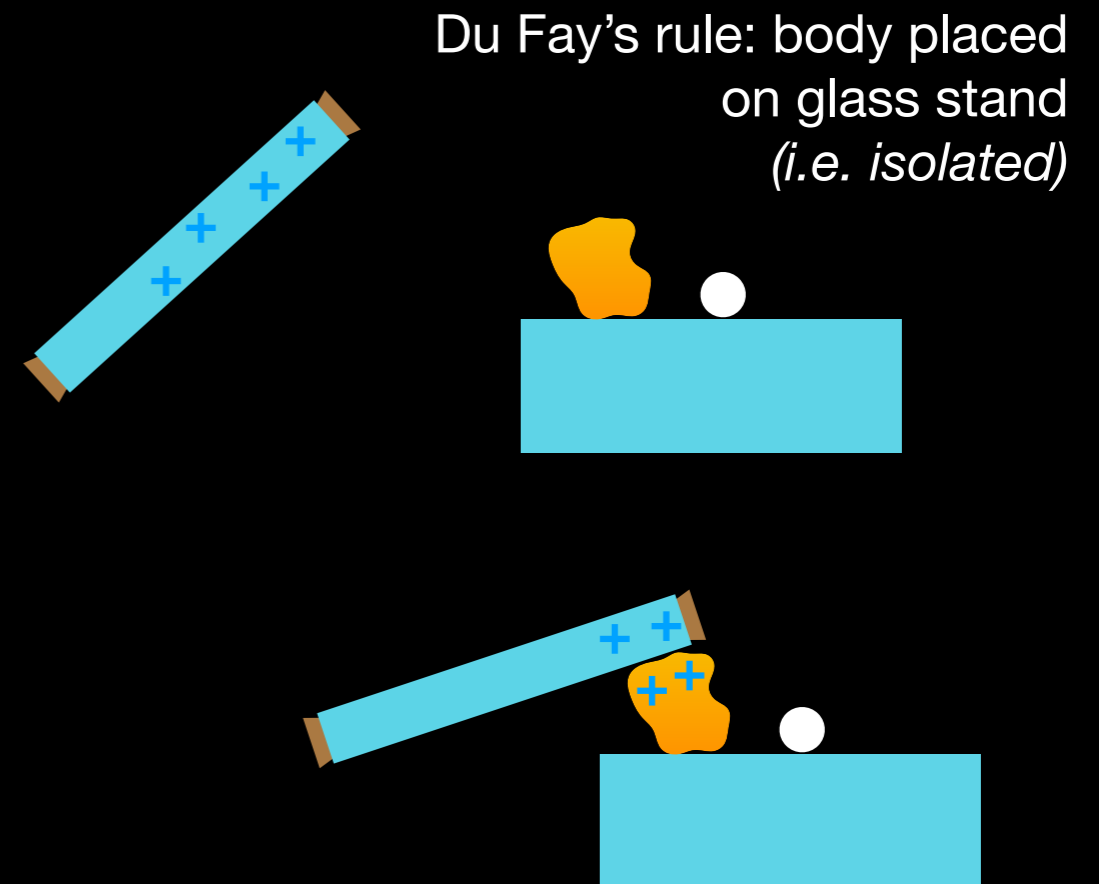
Nobody managed to reproduce his experiments!

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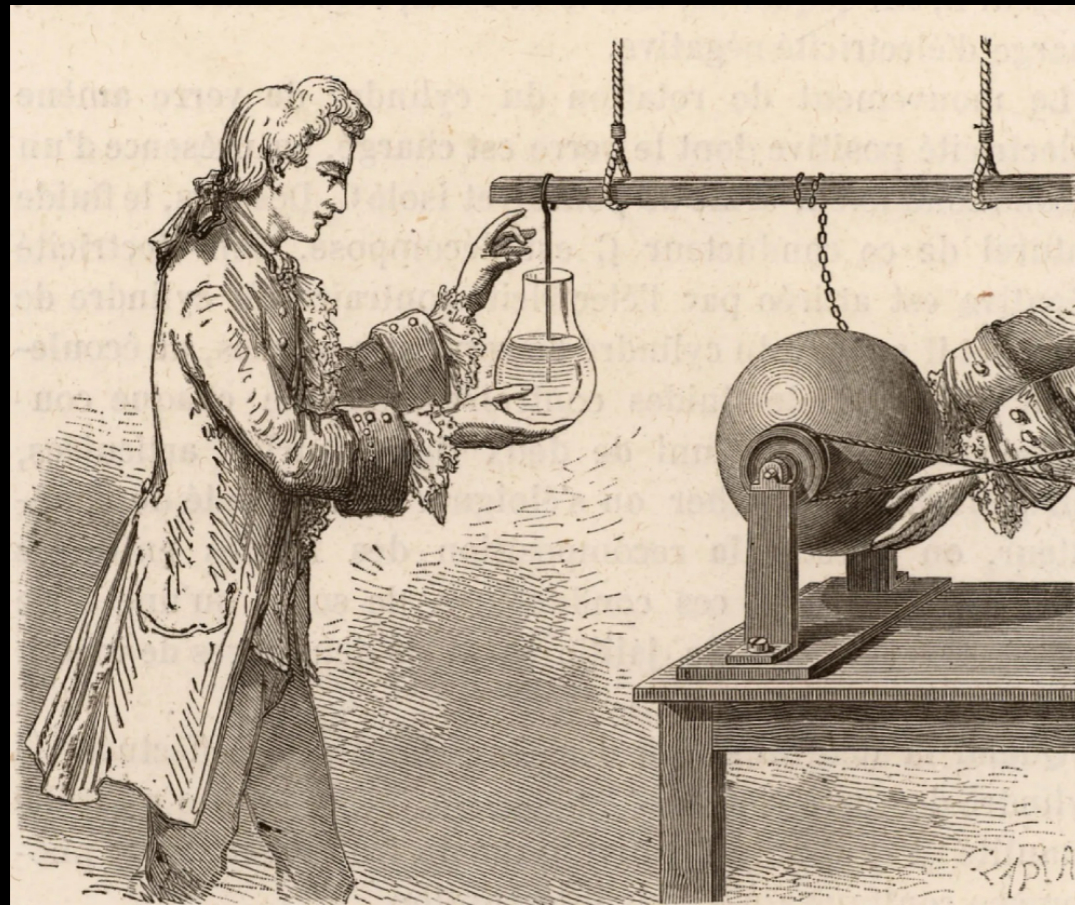


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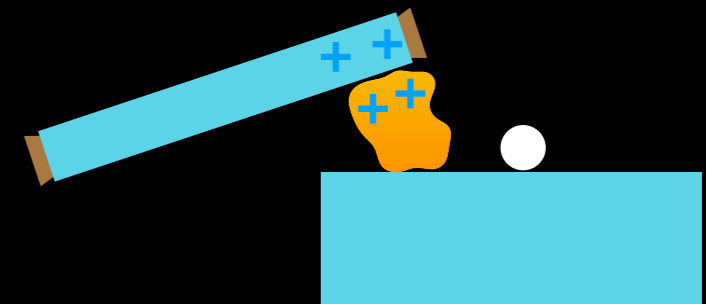
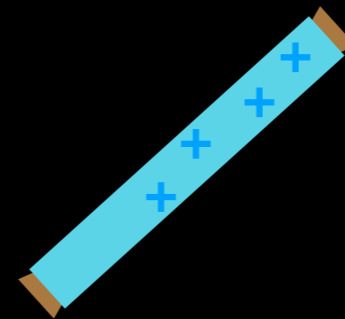
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Du Fay's rule: body placed
on glass stand
(i.e. isolated)

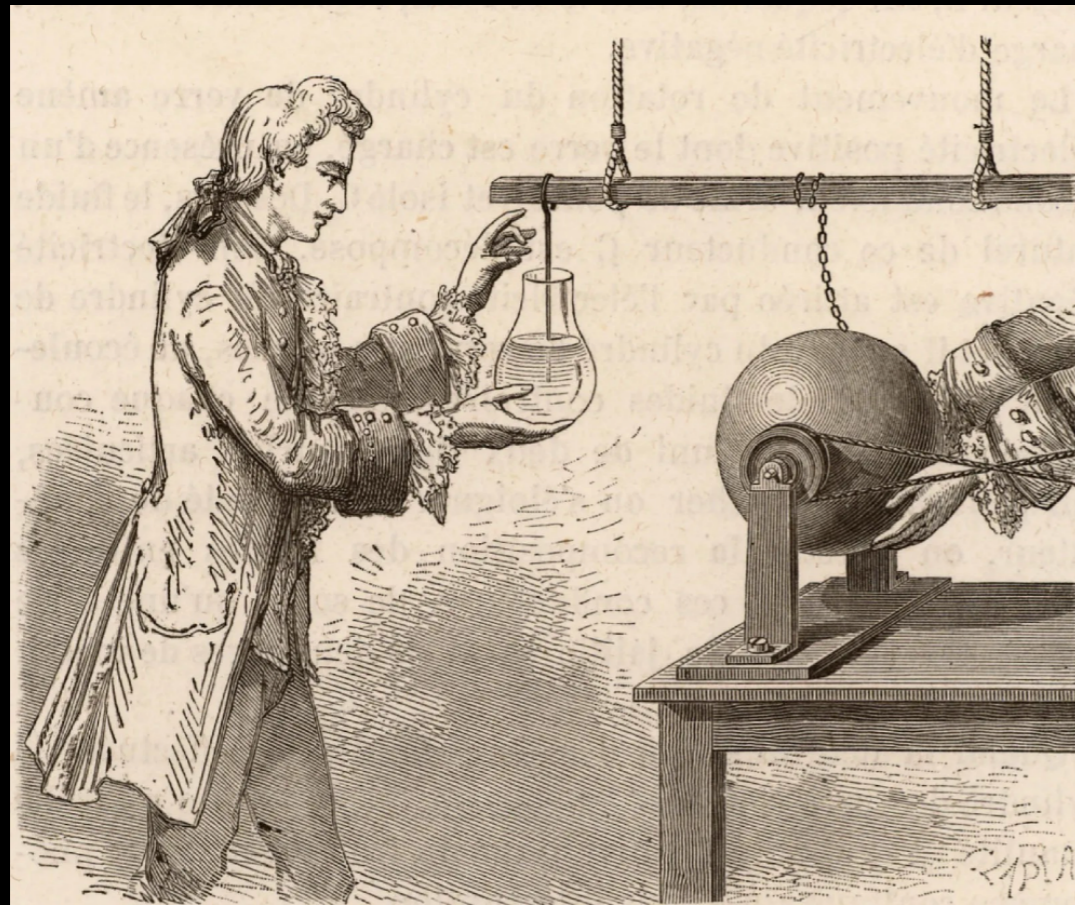


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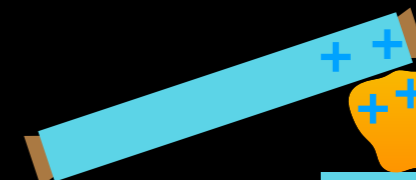
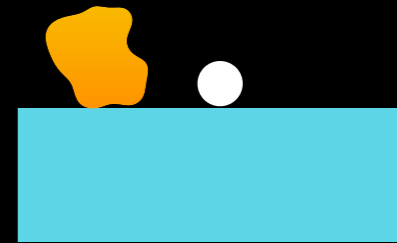
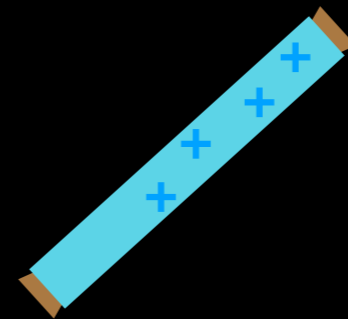
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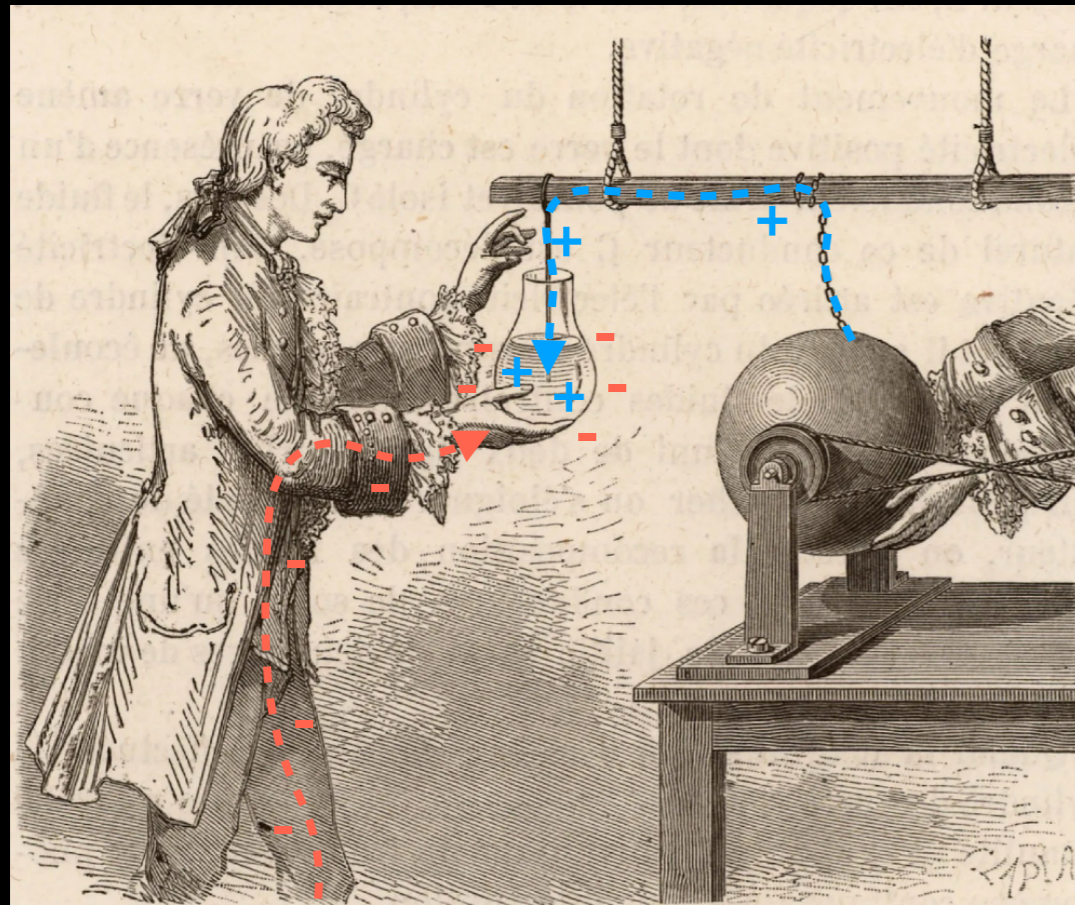
Von Kleist did not know about du Fay's rule!

Defying du Fay's rule

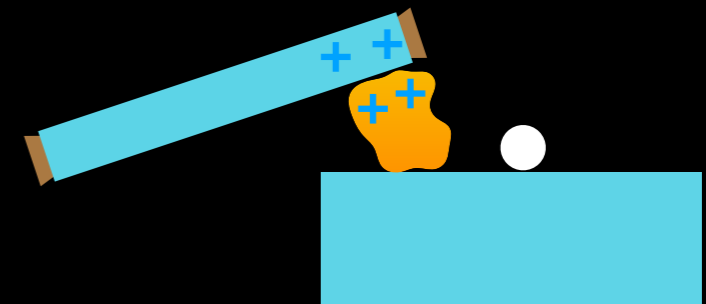
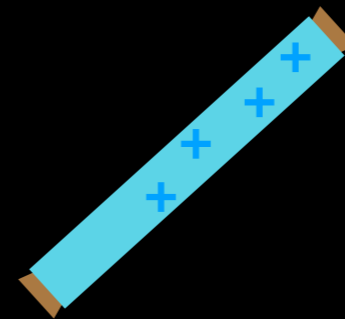
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The rediscovery at Leyden

Pieter van Musschenbroek:



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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Amusement

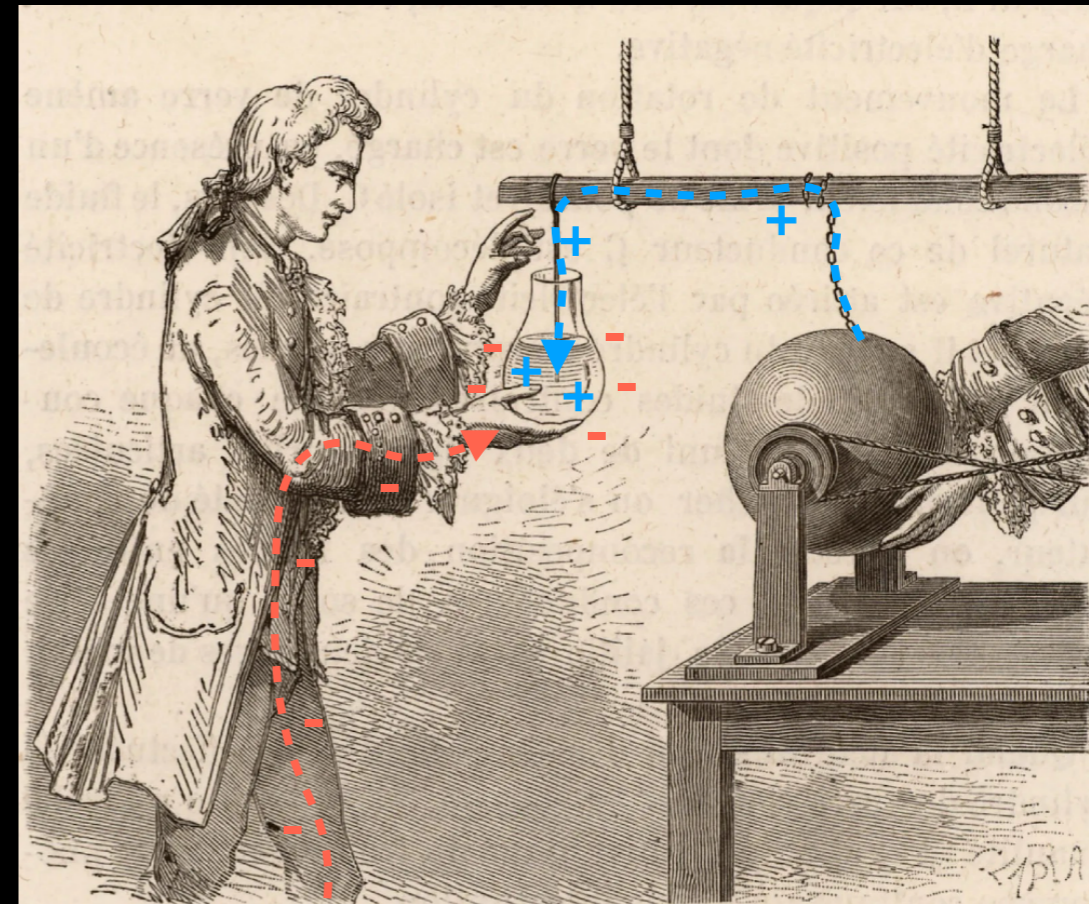
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Amusement



“Terror”

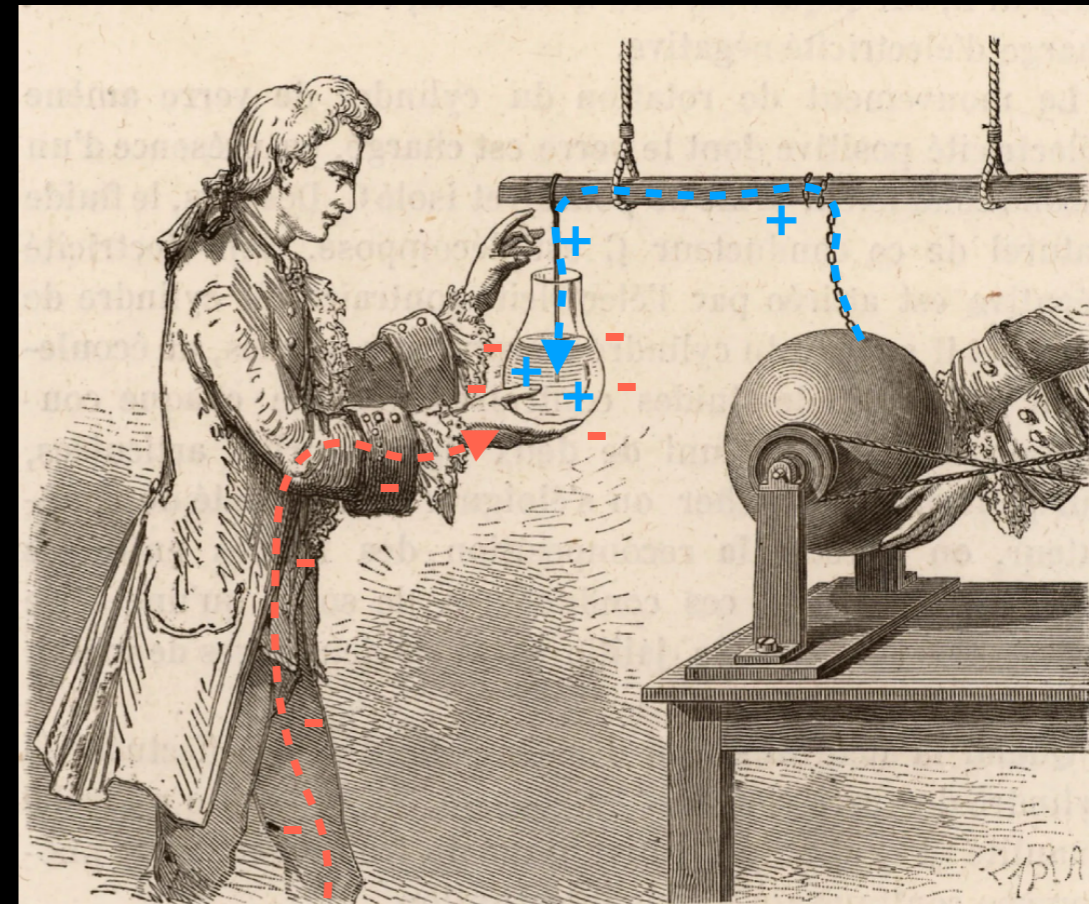
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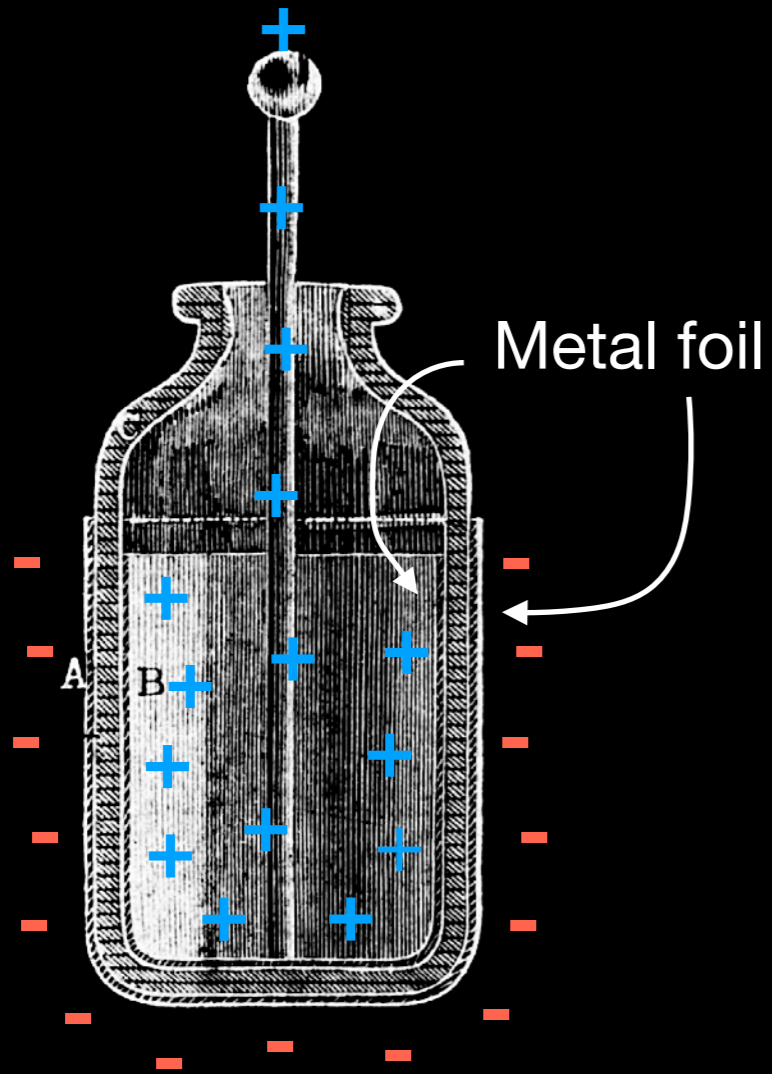


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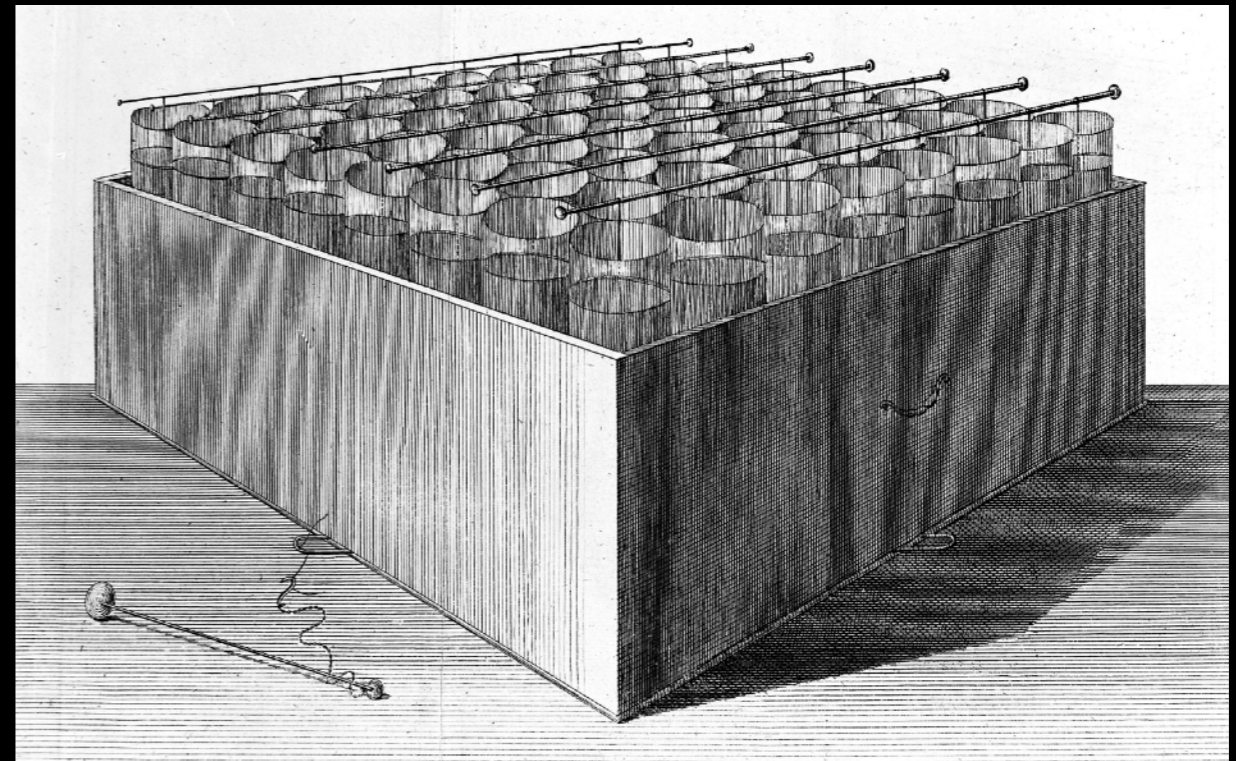
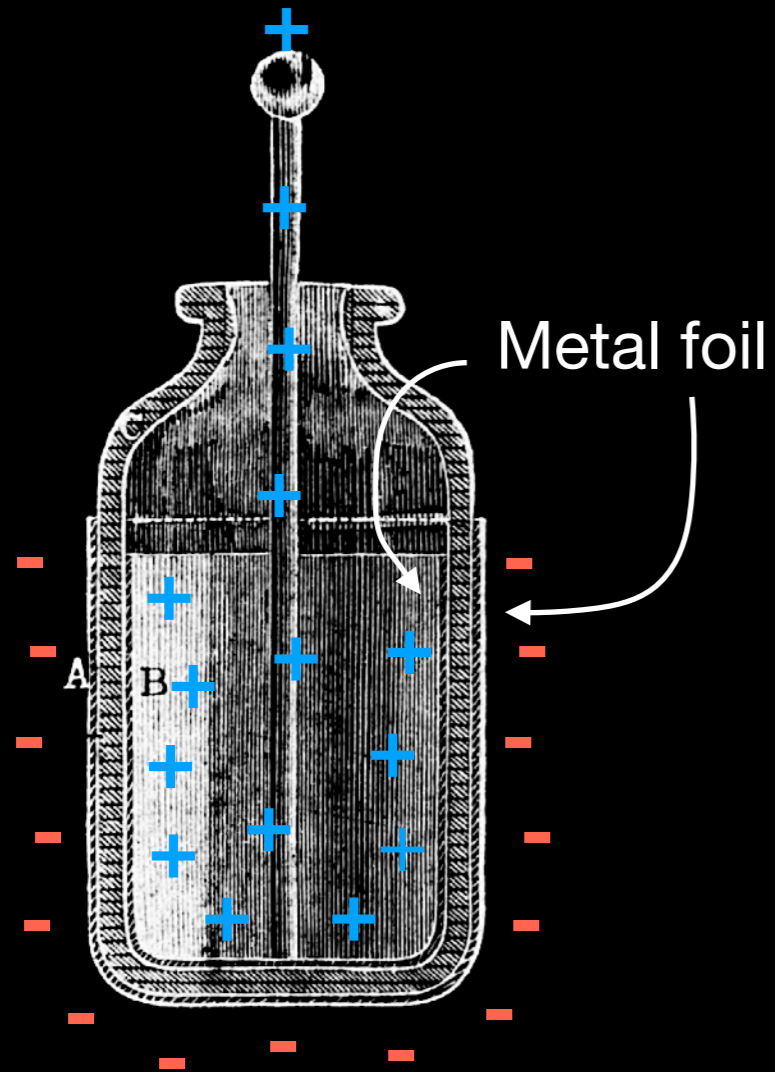
“No one ever thought that the Rule of du Fay must allow an exception in the case of glass.”

Experiments with the “Leyden Jar”

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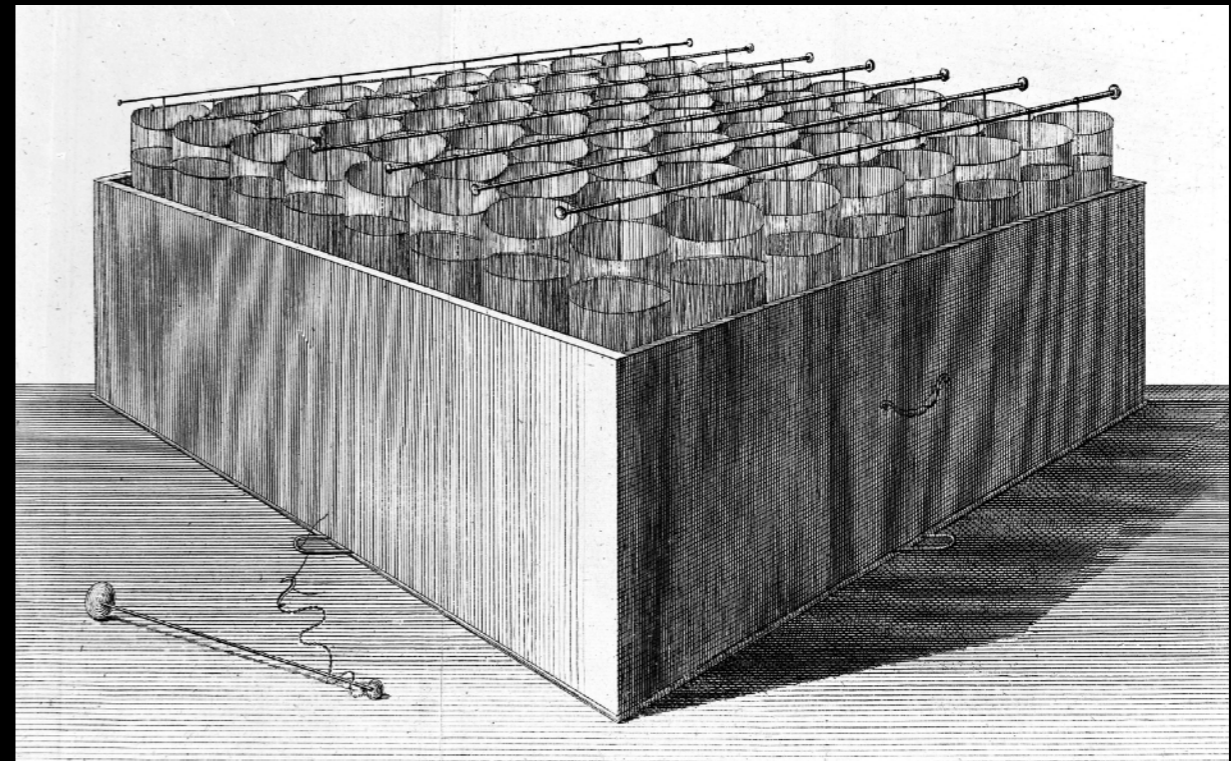
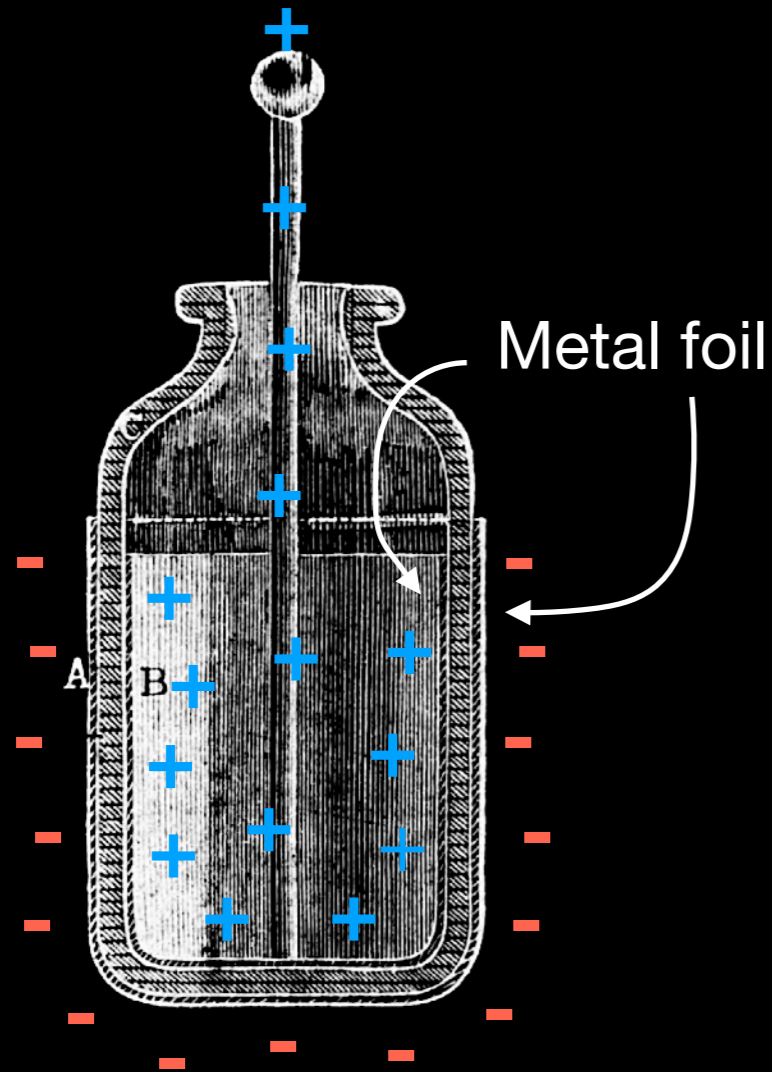


Experiments with the “Leyden Jar”



“Battery” of Leyden Jars

Experiments with the “Leyden Jar”

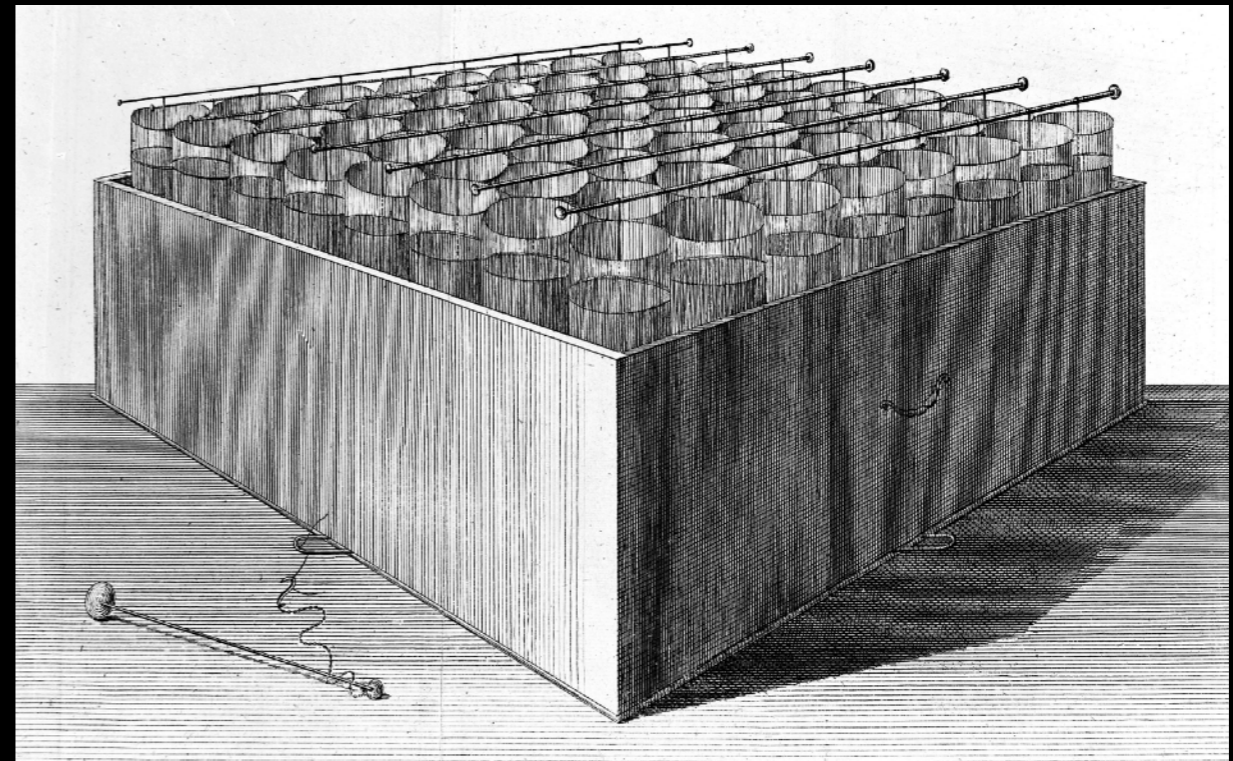
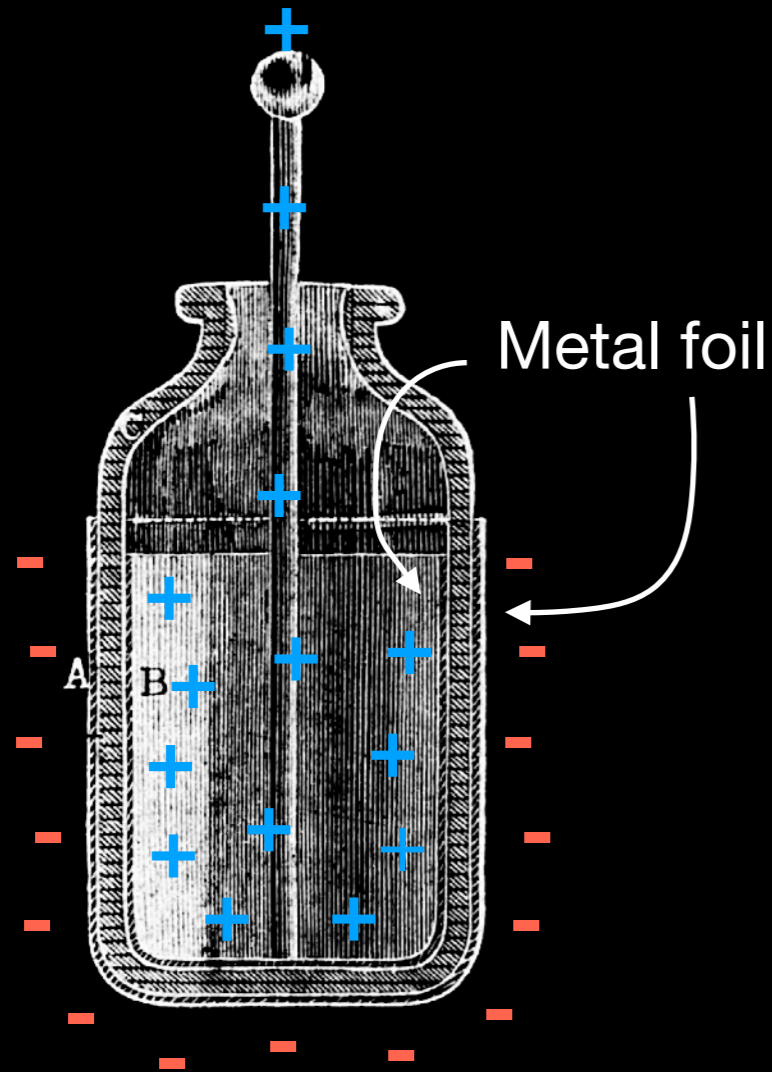


“Battery” of Leyden Jars

Benjamin Franklin (1750):

“Two nights ago, being about to kill a turkey by the shock from two large glass jars, I inadvertently took the whole through my own arms [...]”

Experiments with the “Leyden Jar”



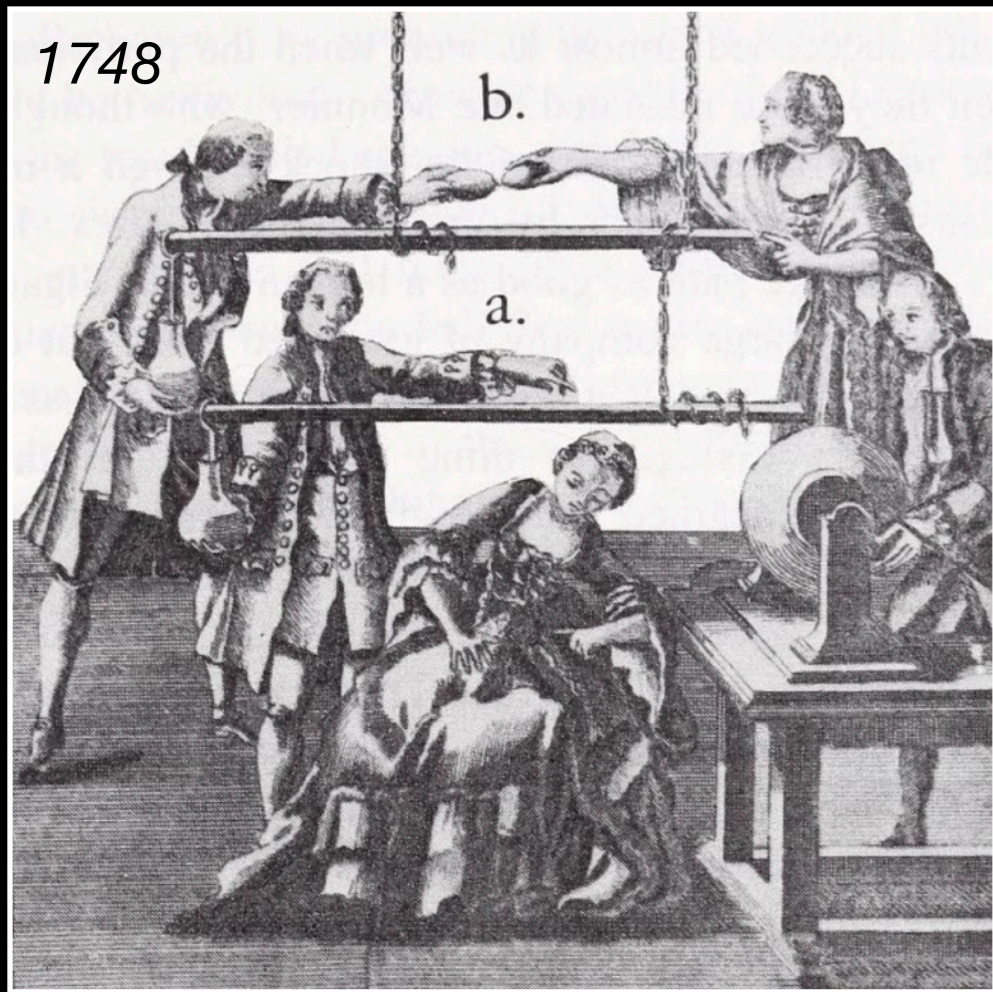
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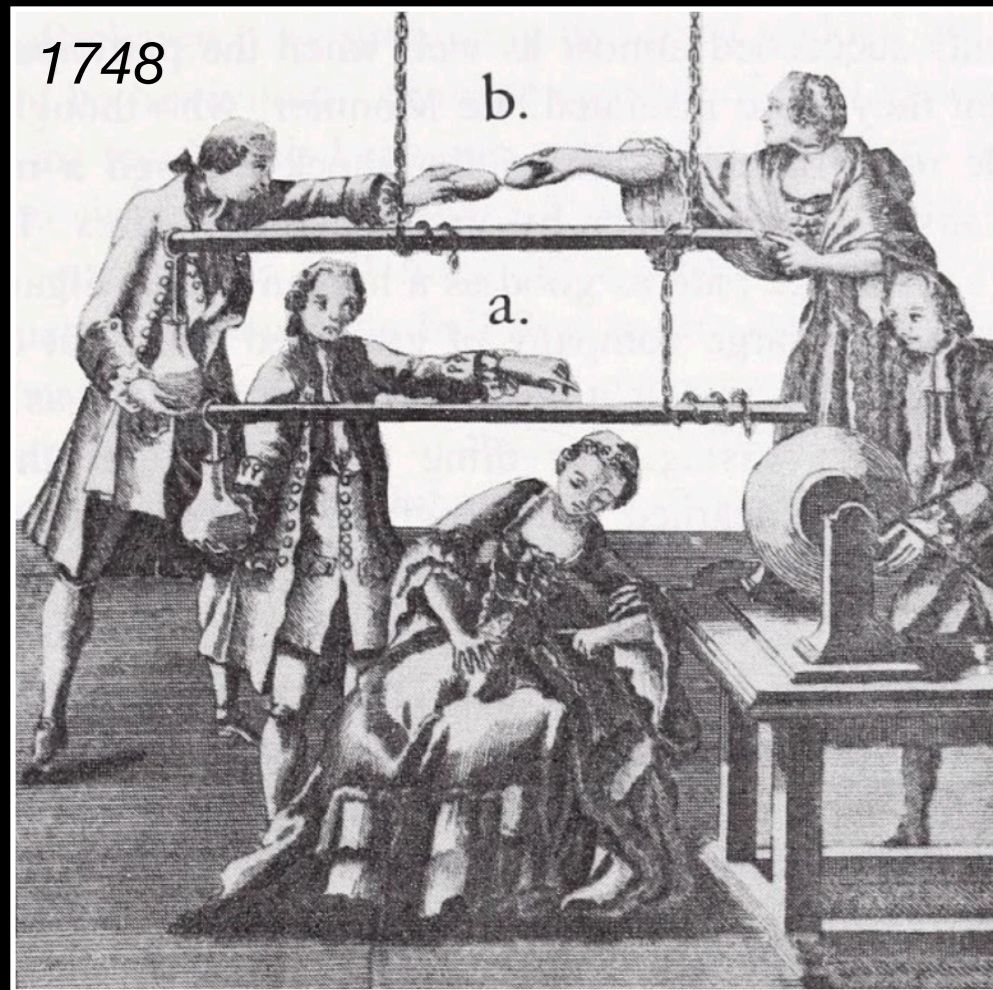
“Two nights ago, being about to kill a turkey by the shock from two large glass jars, I inadvertently took the whole through my own arms [...]”

“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



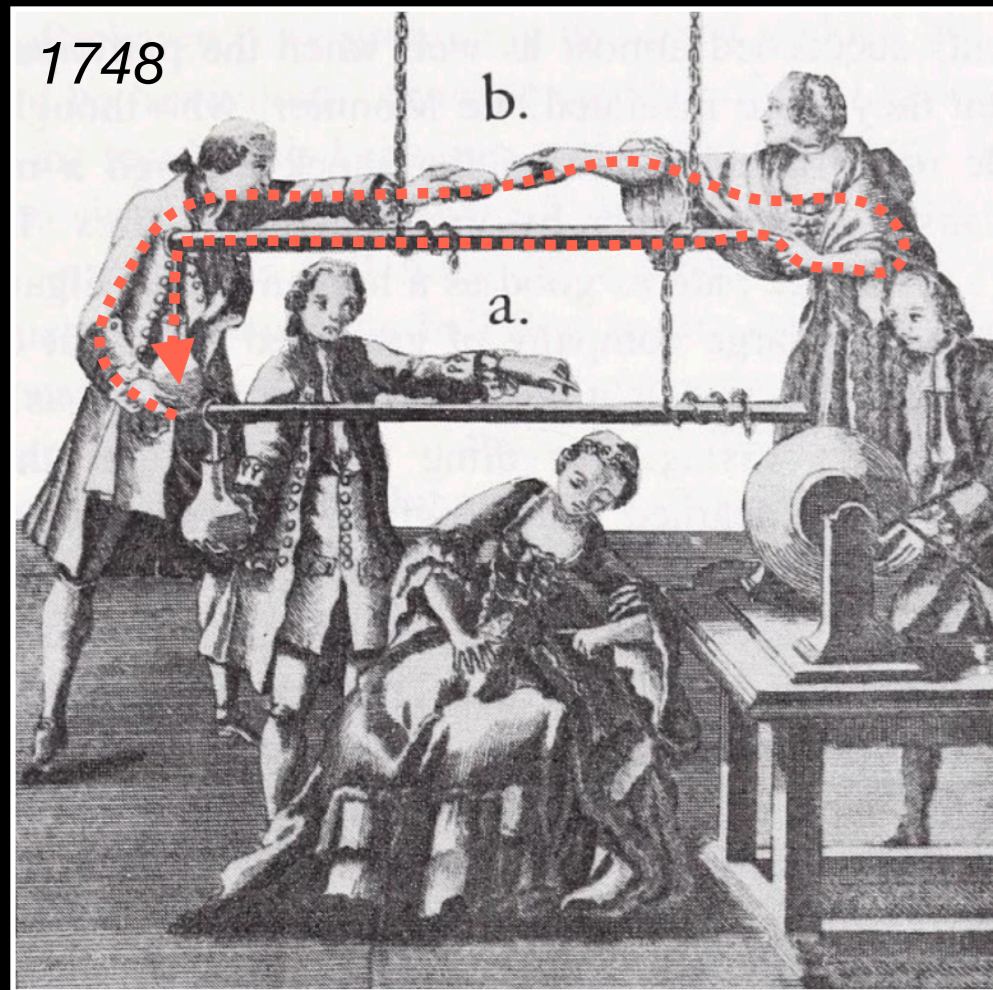
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Discovery of the electrical “circuit”:

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

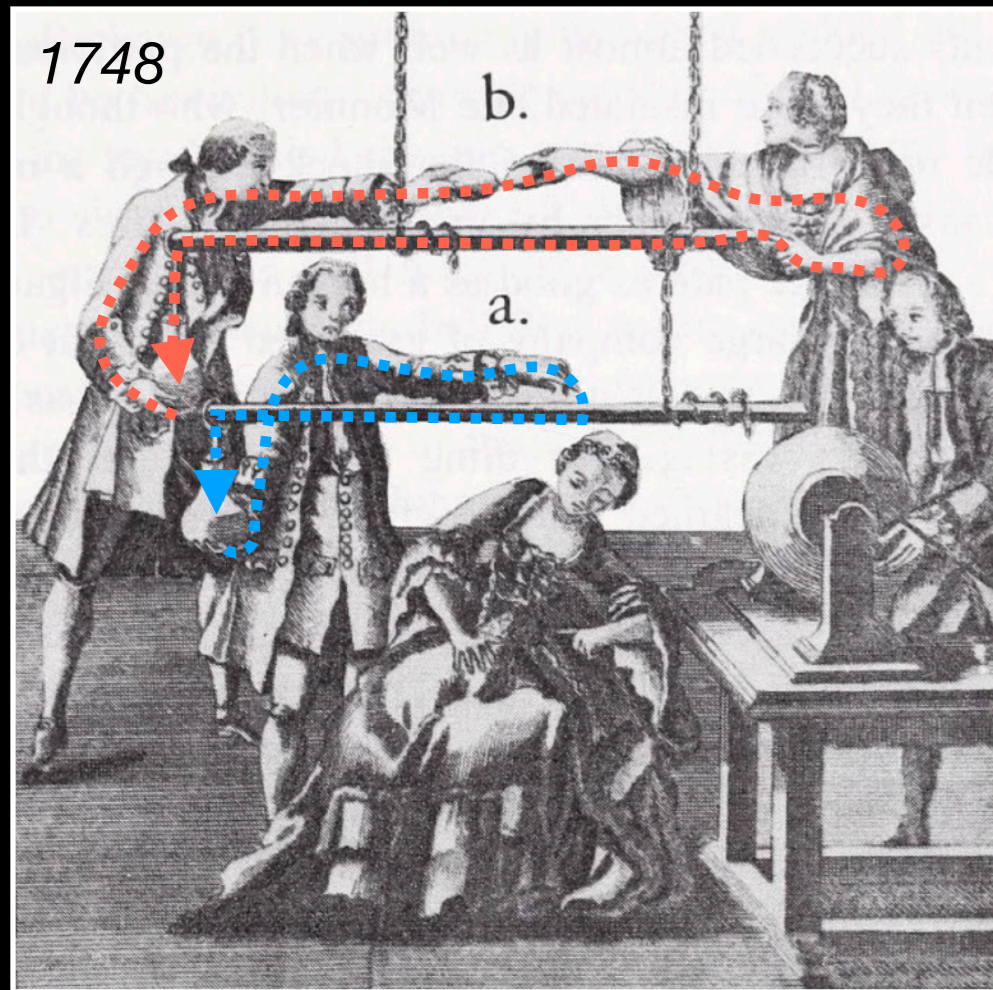
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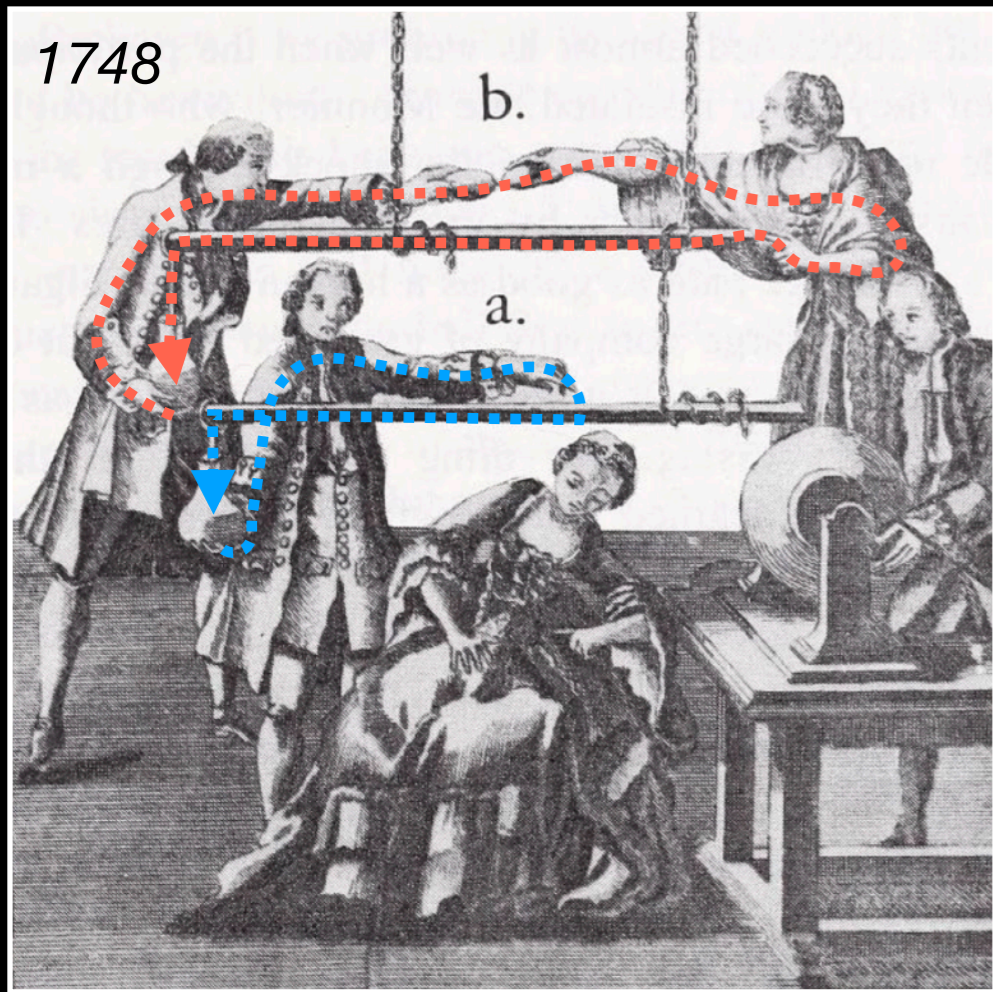
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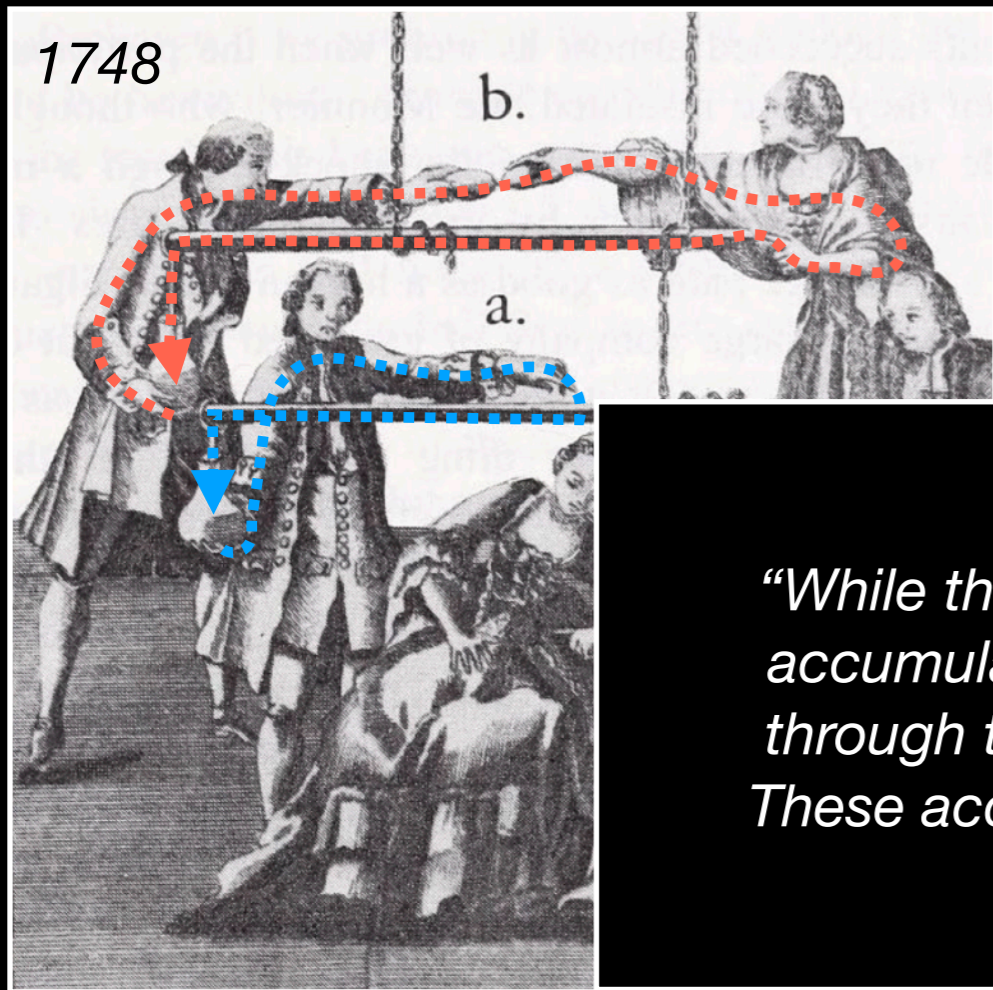
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Japanese
“discharge train”



“Mass electrifications” à la Leyden

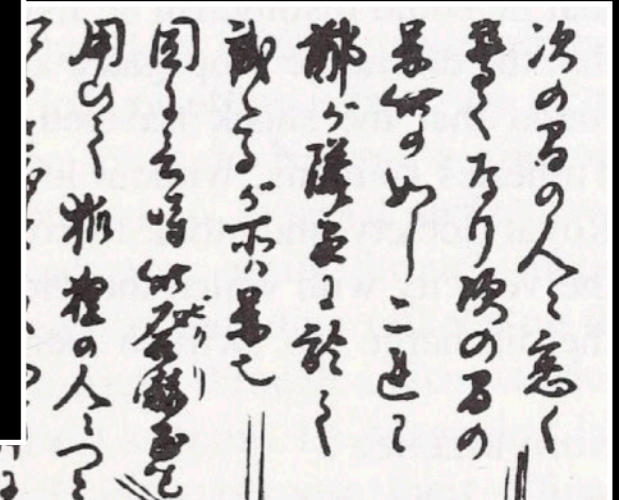


Discovery of the electrical “circuit”:

(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
“discharge train”



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”

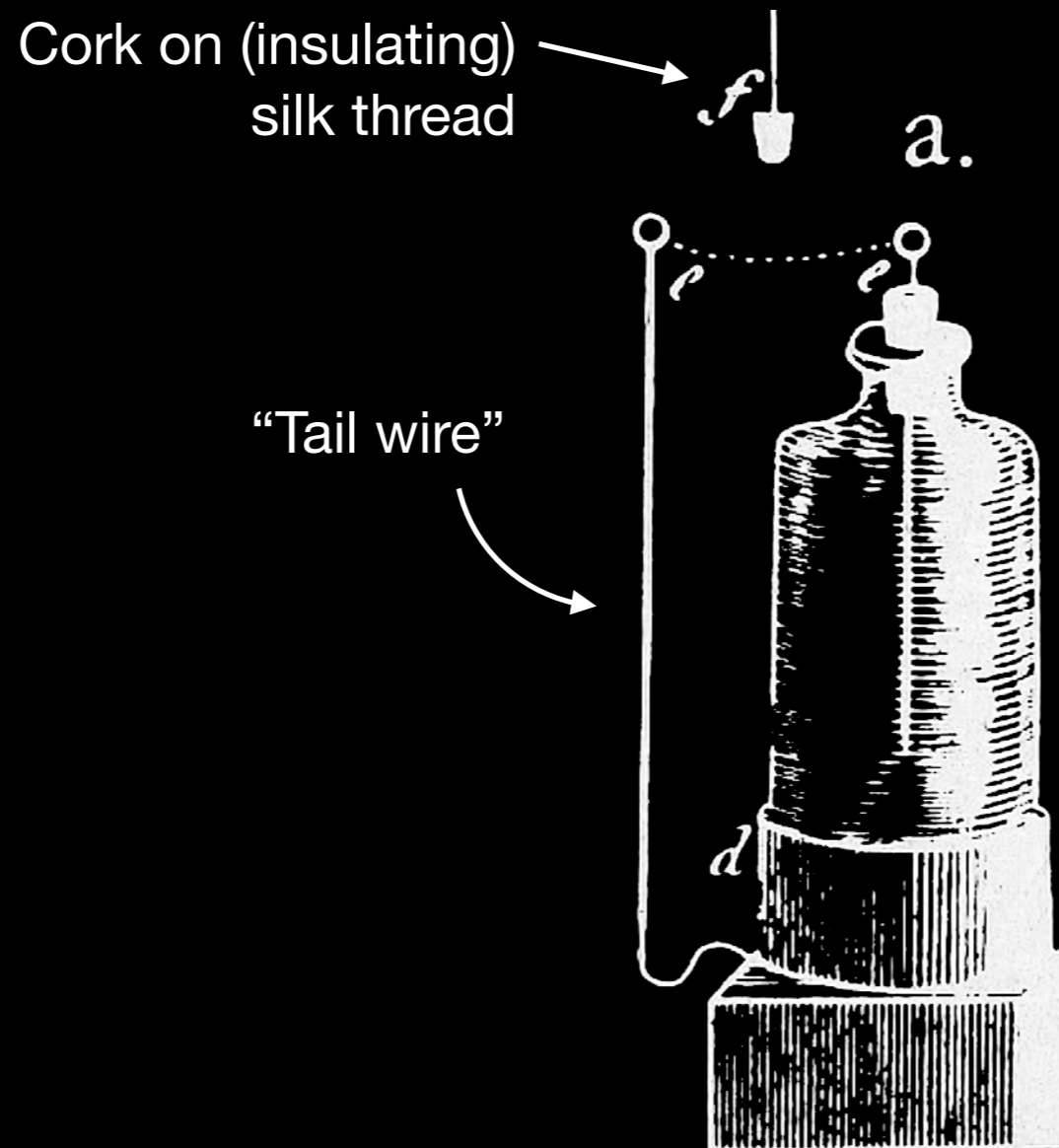
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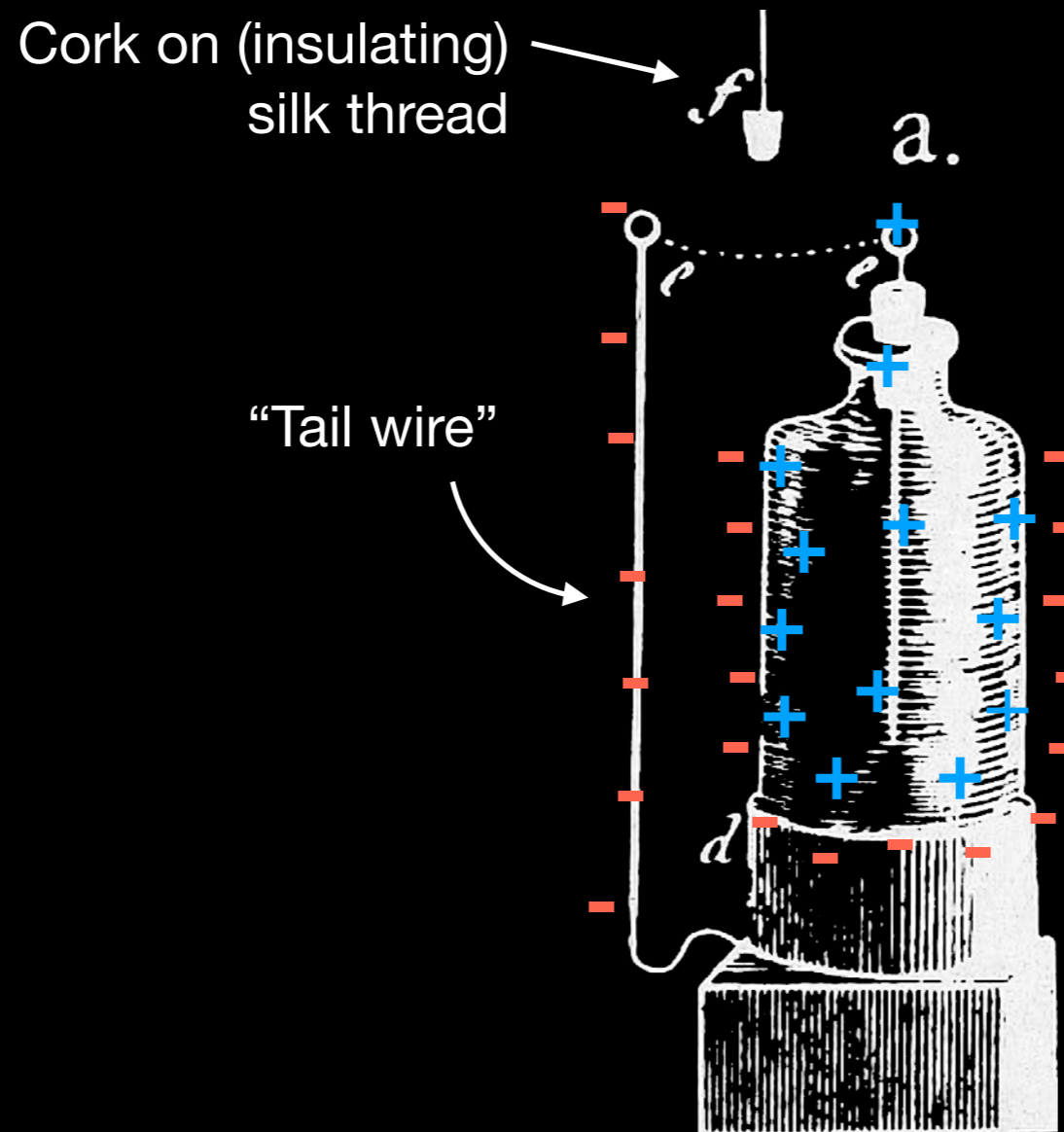


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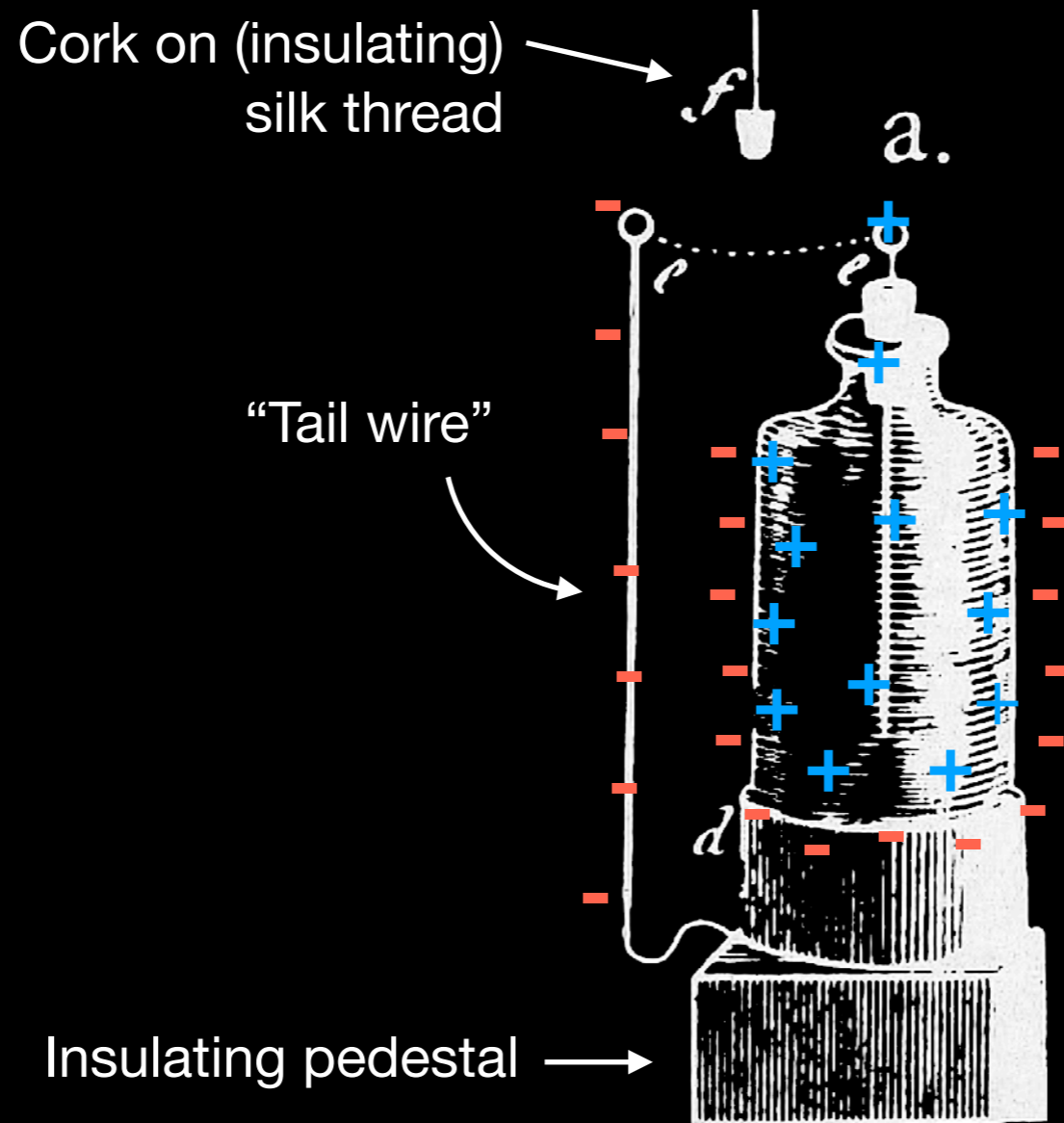


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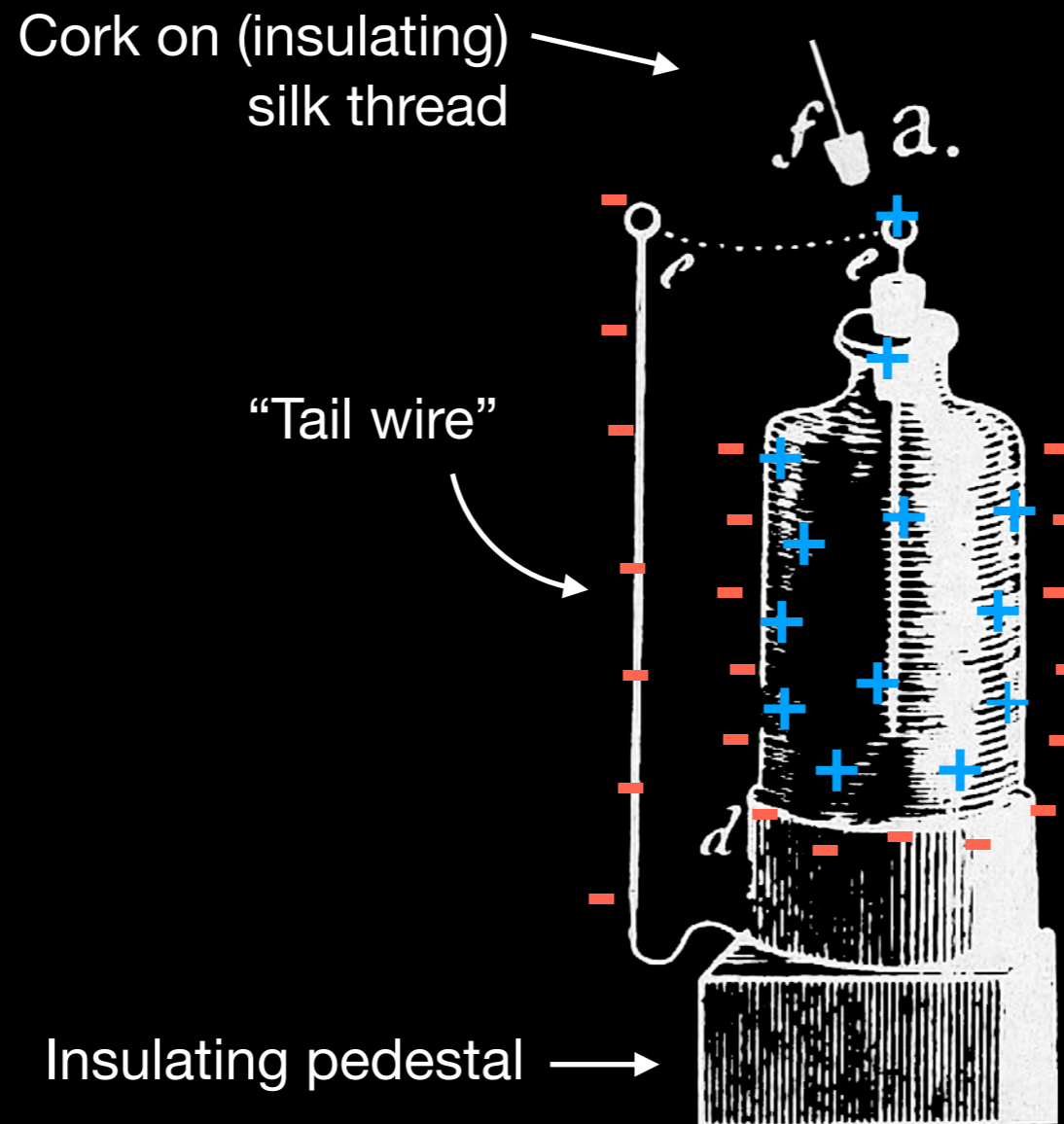


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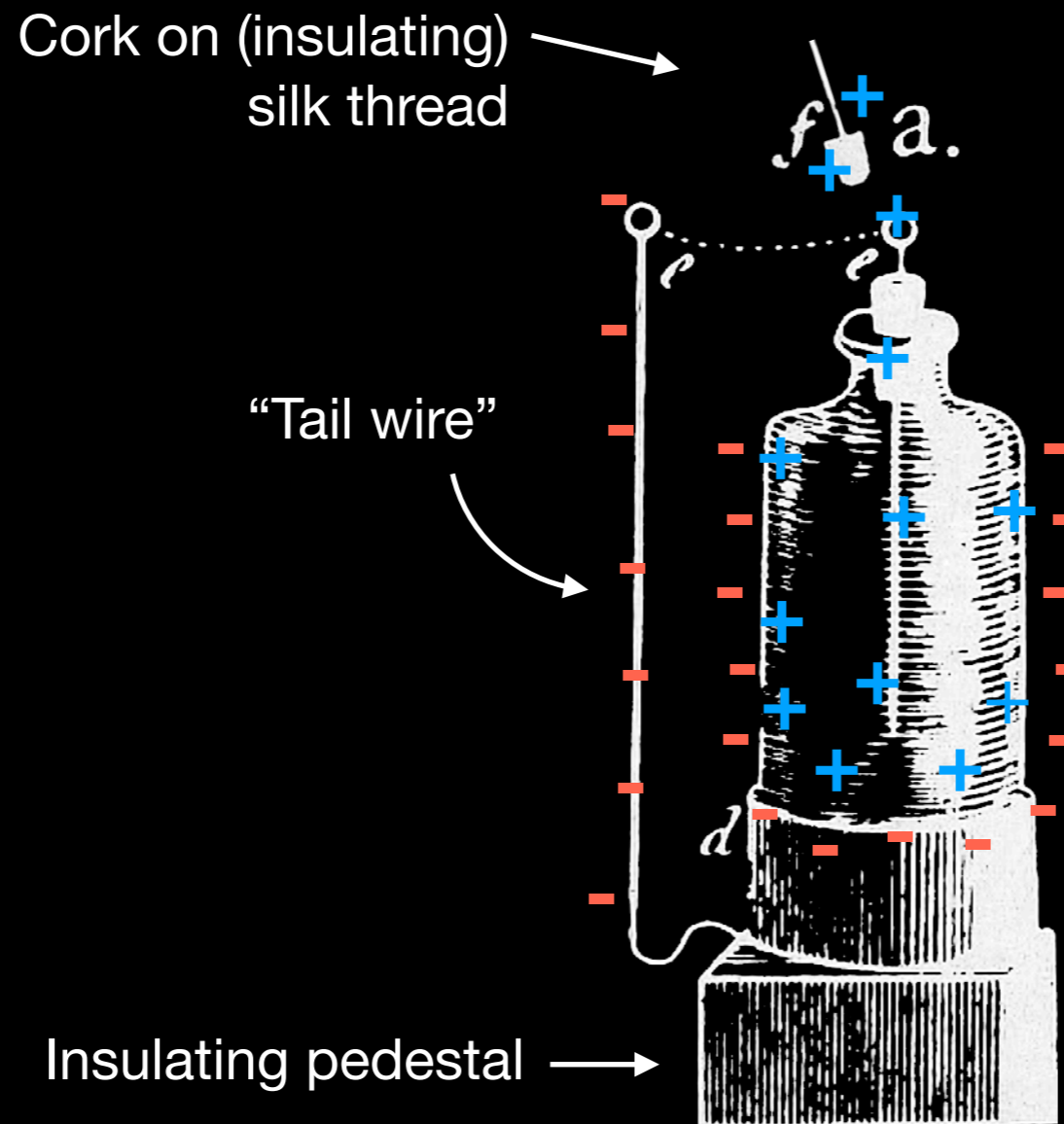


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“Positive” = “Vitreous”

“Negative” = “Resinous”

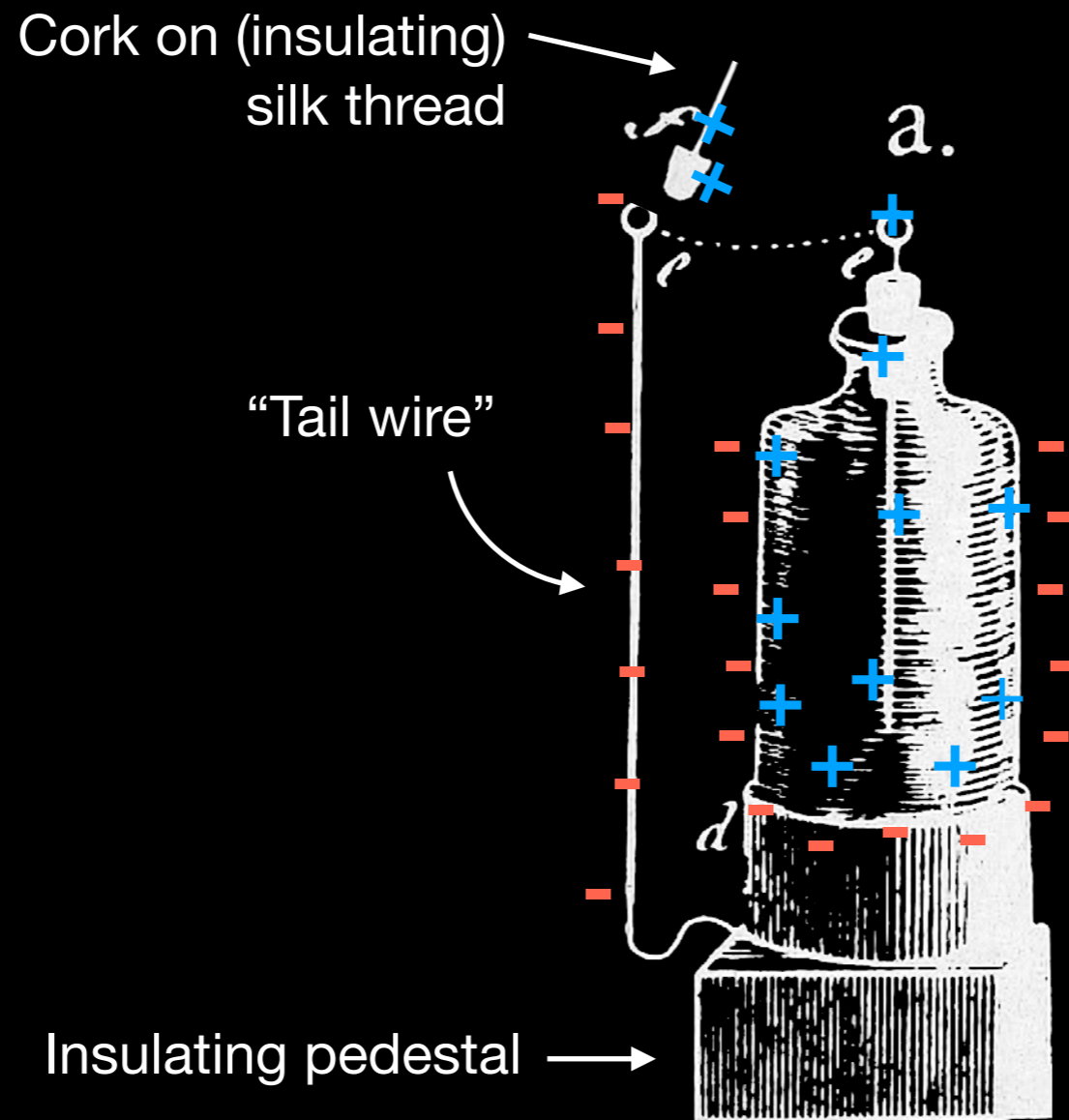


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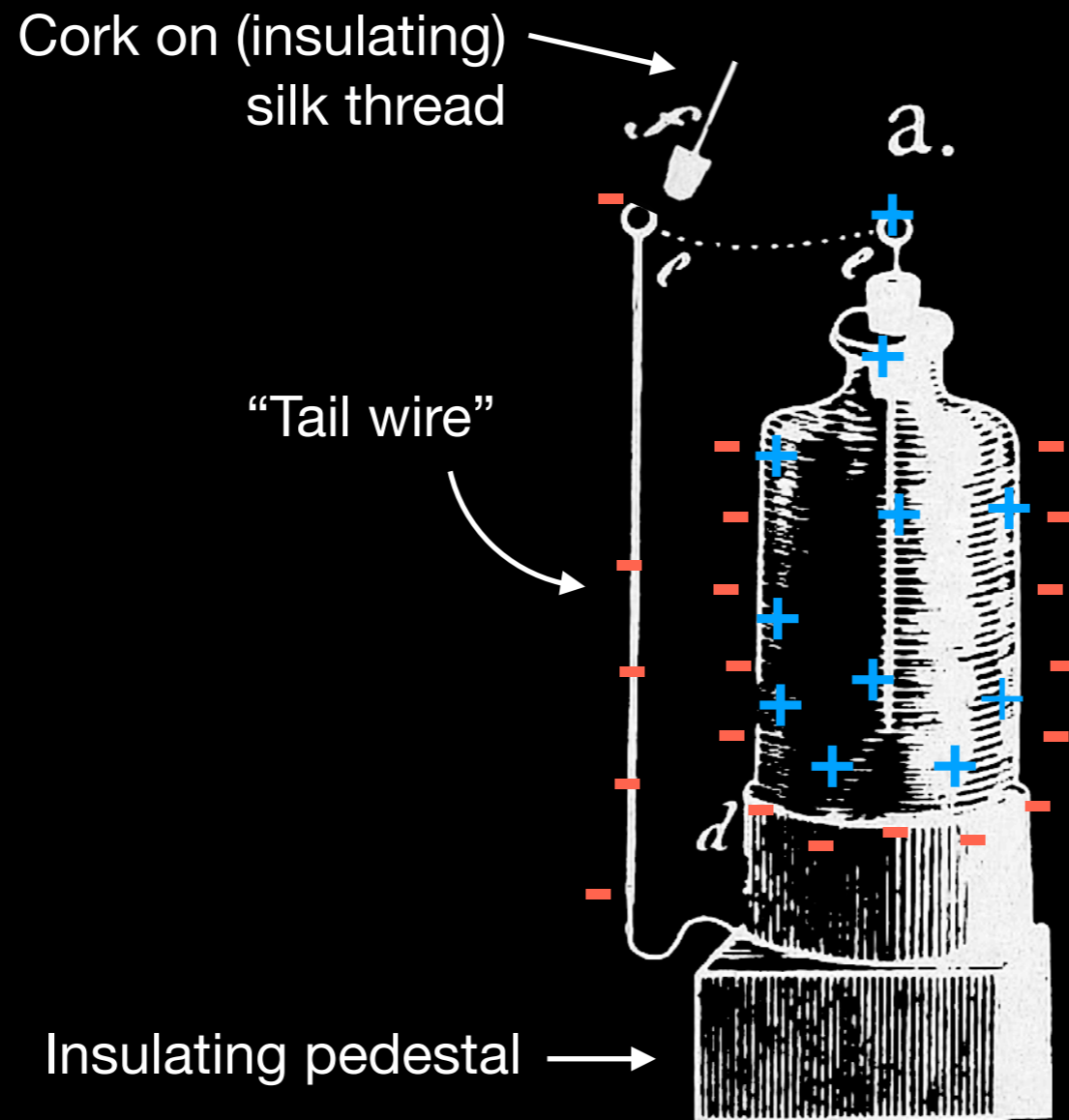


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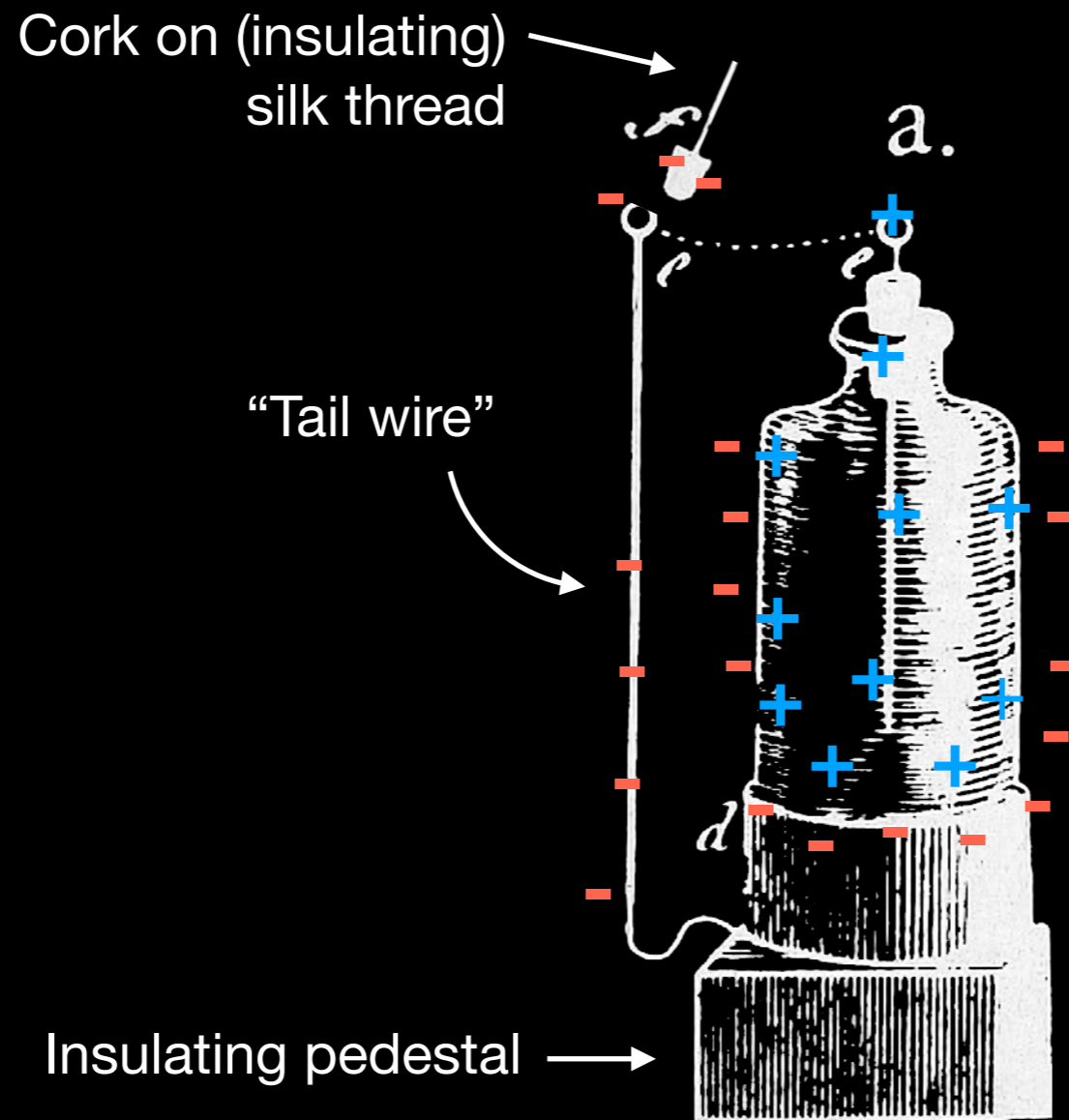


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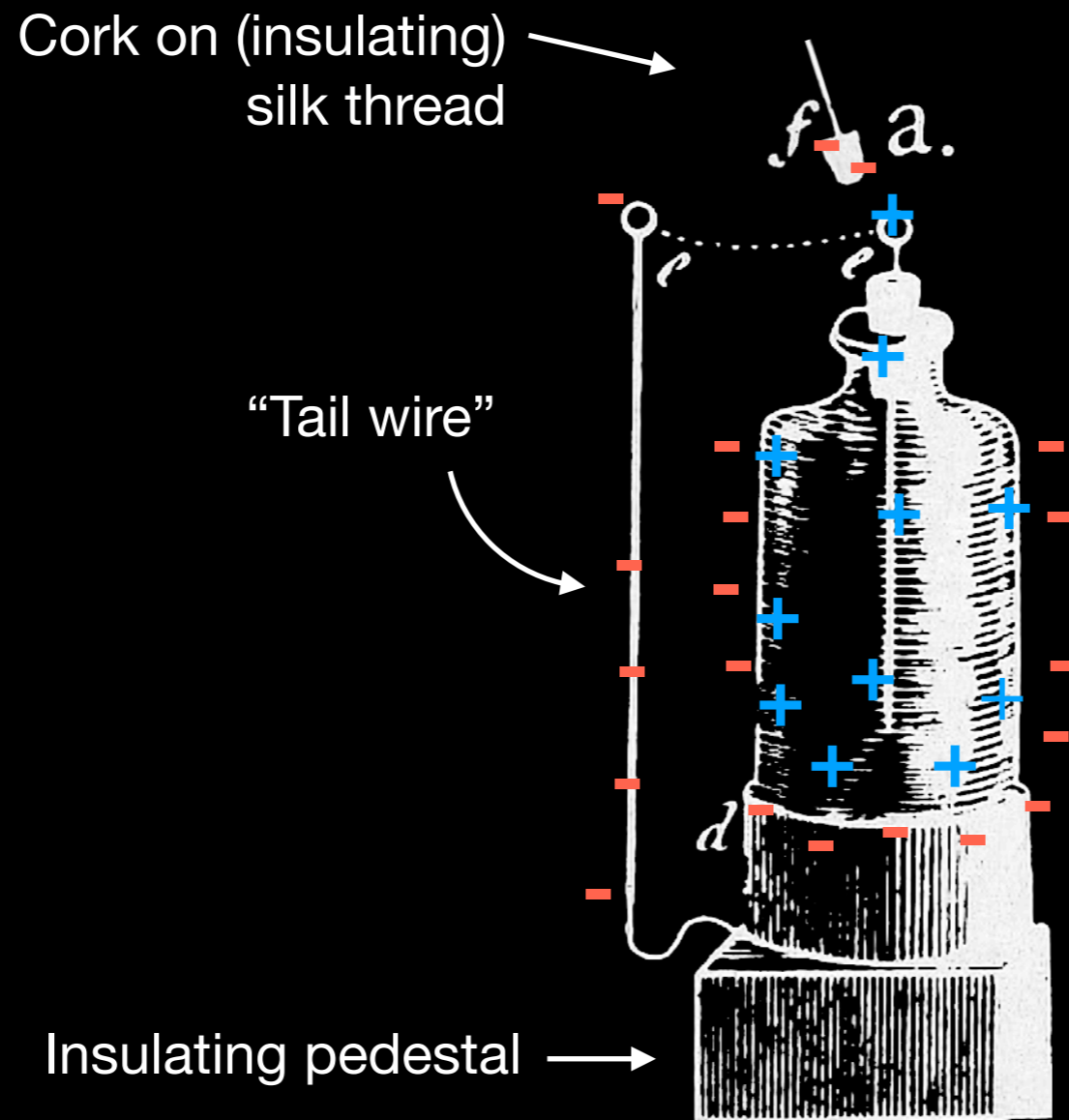


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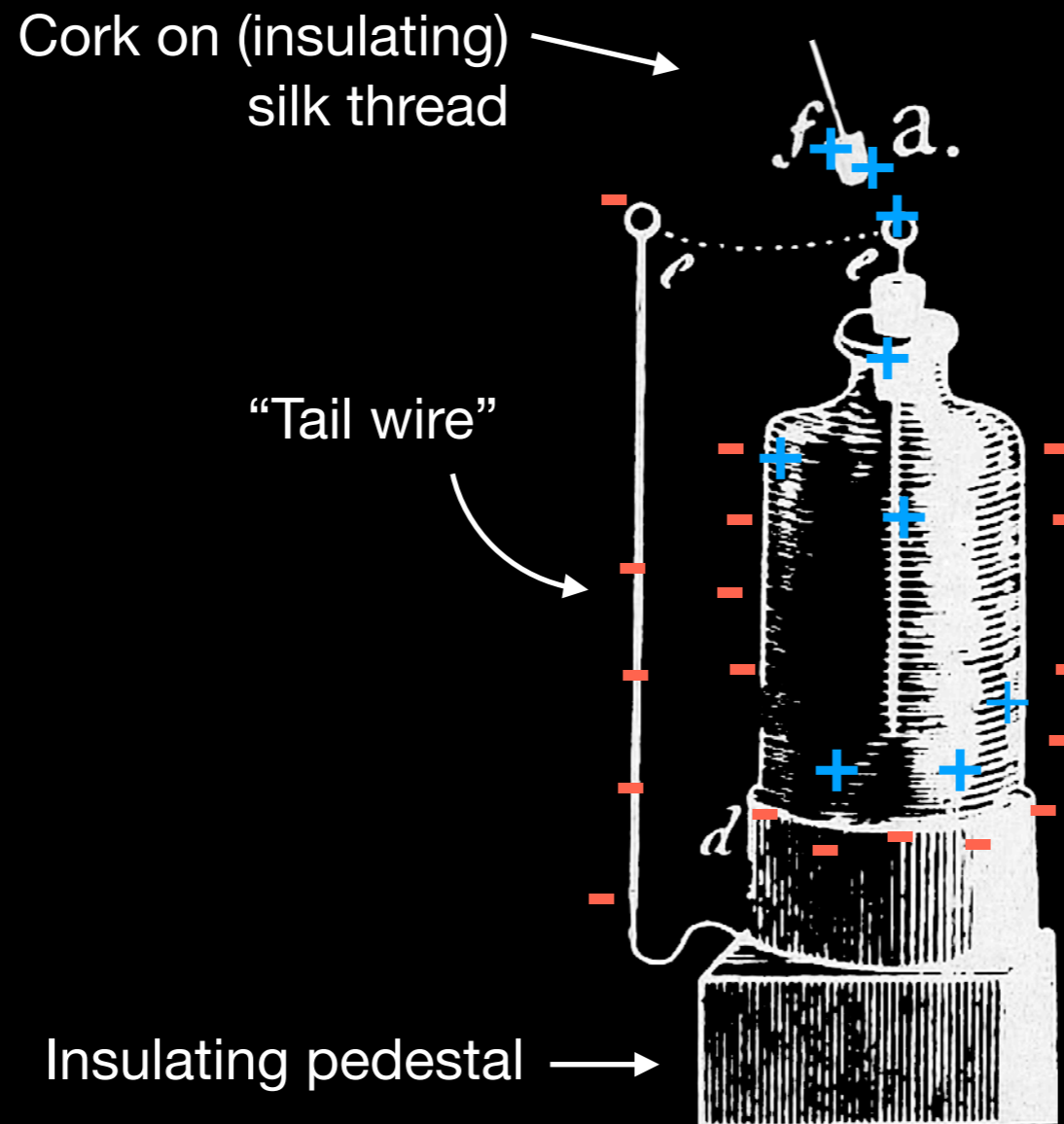


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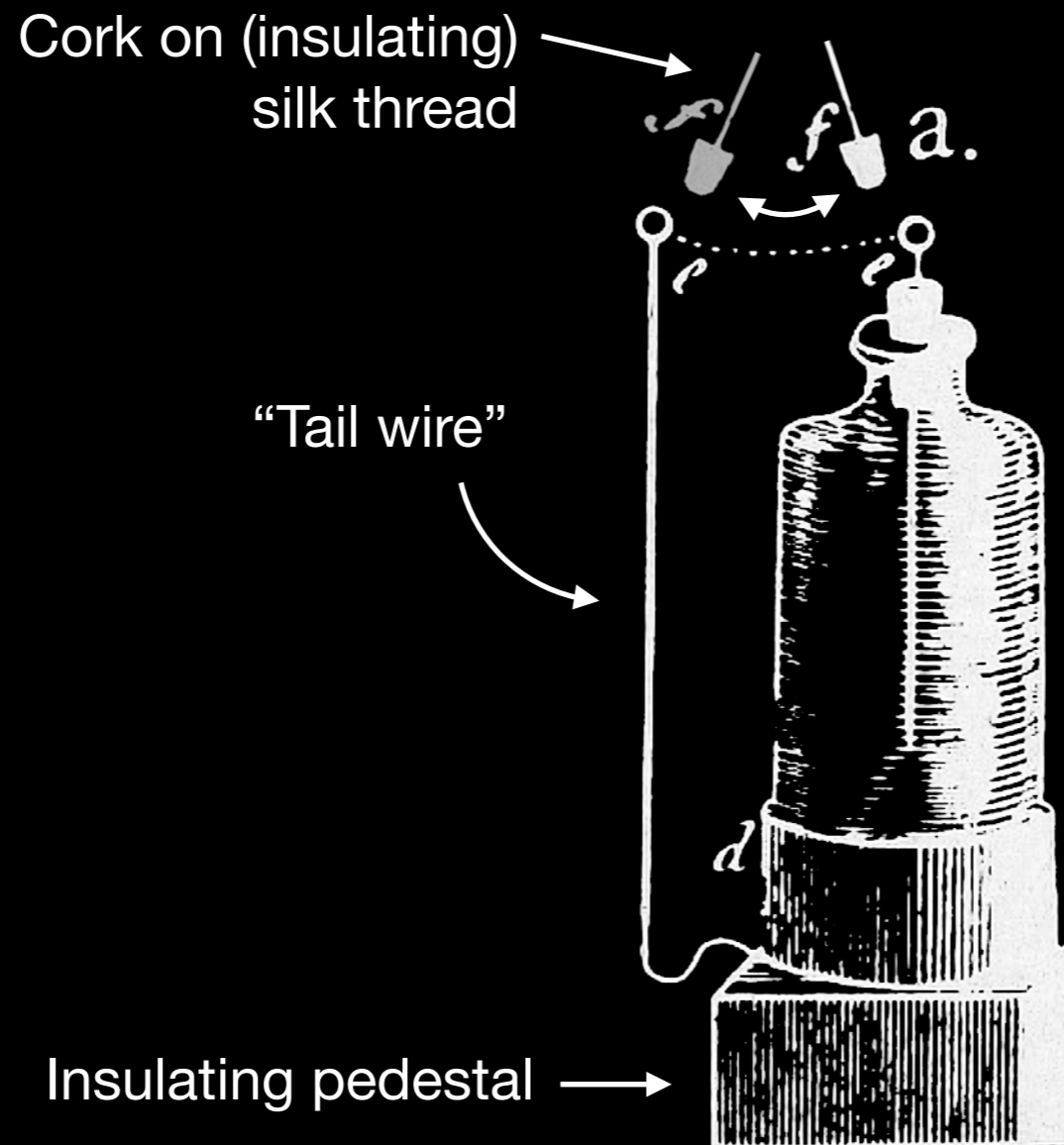


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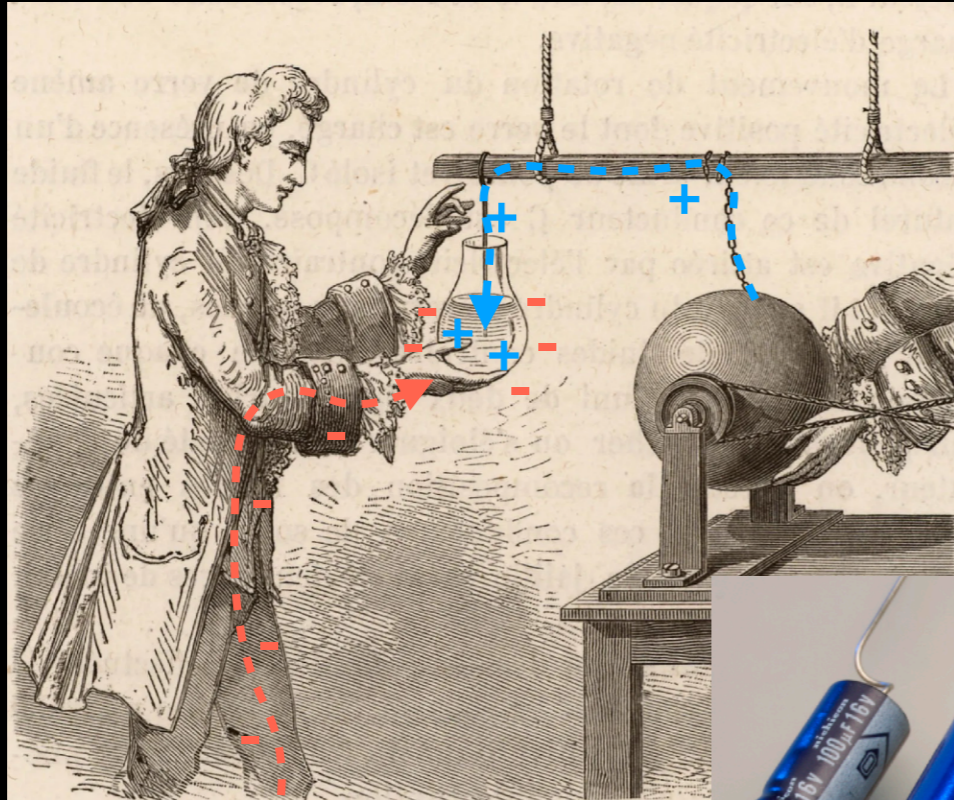
“Negative” = “Resinous”



The electricity fully disappears!

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 is electrised negatively (or minus).”



Can only charge the capacitor if both terminals are connected



Electricity
leaks!

insulating pedestal



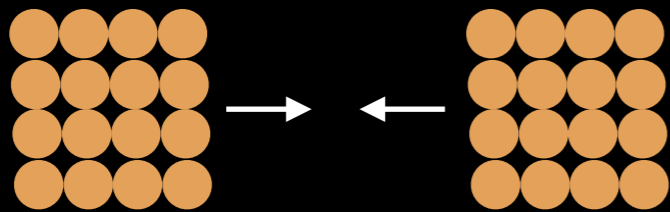
The nature of electricity ...

... according to Benjamin Franklin

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“Common matter”

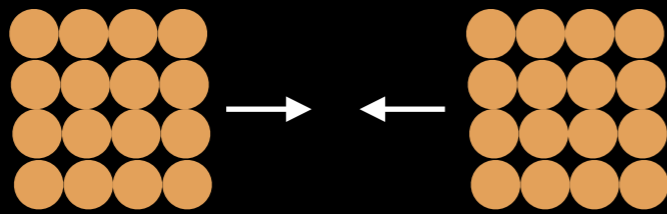


Mutually attracting

The nature of electricity ...

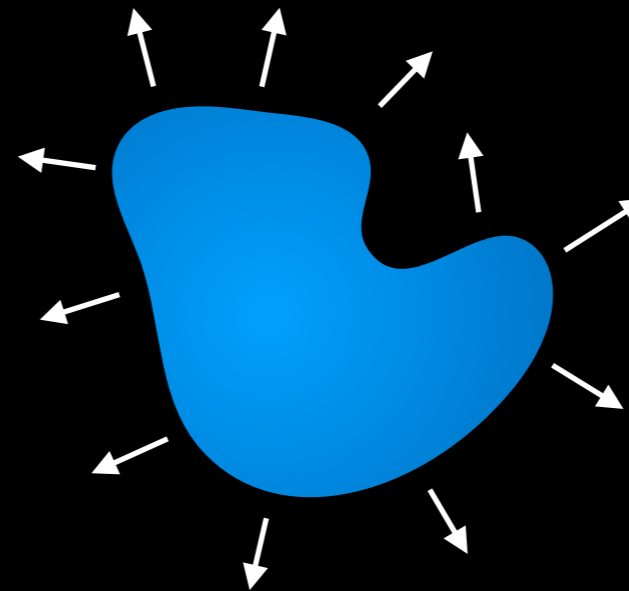
... according to Benjamin Franklin

“Common matter”



Mutually attracting

“Electrical matter”

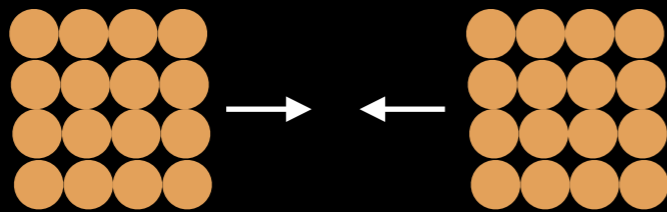


“Subtle fluid”,
mutually repelling

The nature of electricity ...

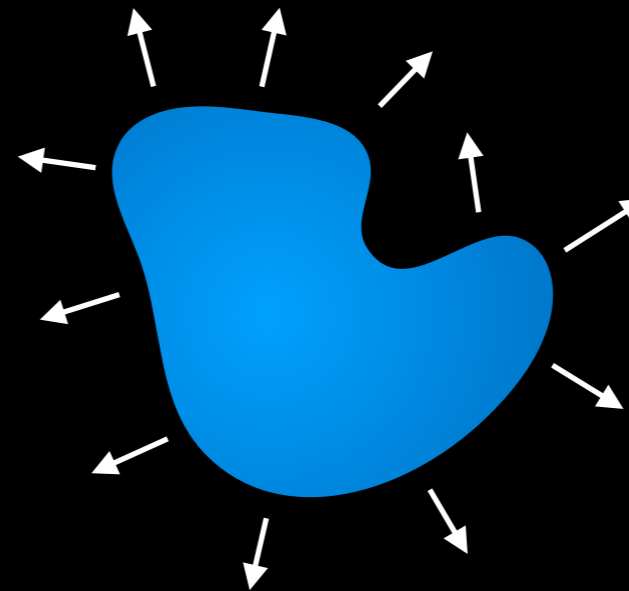
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“Neutral matter”

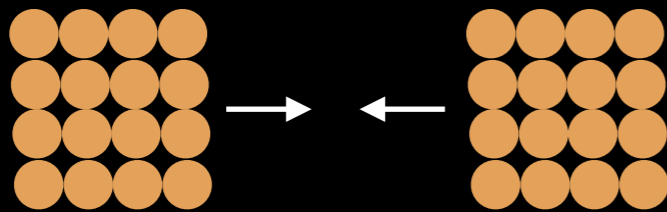


Common matter and electrical matter
attract very strongly

The nature of electricity ...

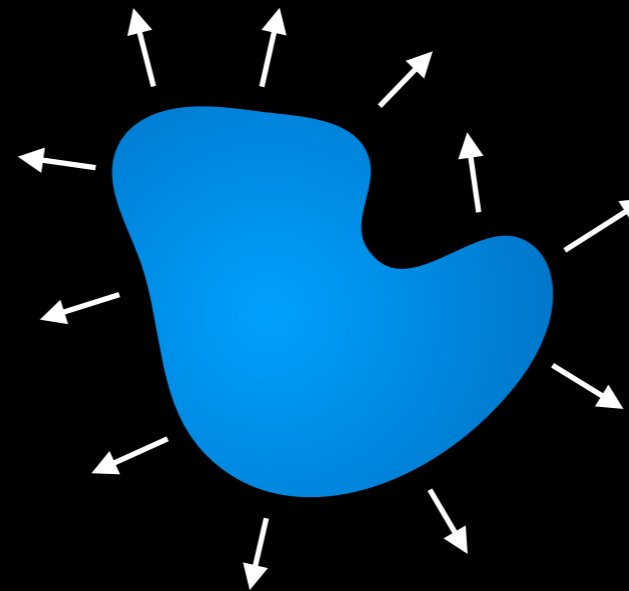
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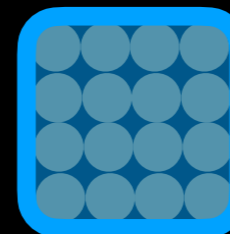
“Subtle fluid”,
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“Neutral matter”



Common matter and electrical matter
attract very strongly

Electrically charged matter



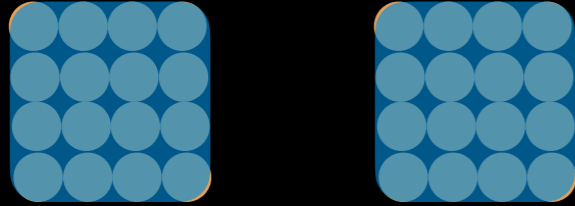
Electrical matter forms
“atmosphere” on surface
of body

The nature of electricity ...

... according to Benjamin Franklin

The nature of electricity ...

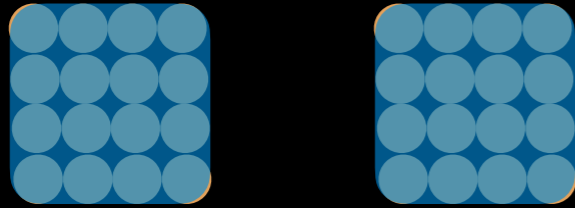
... according to Benjamin Franklin



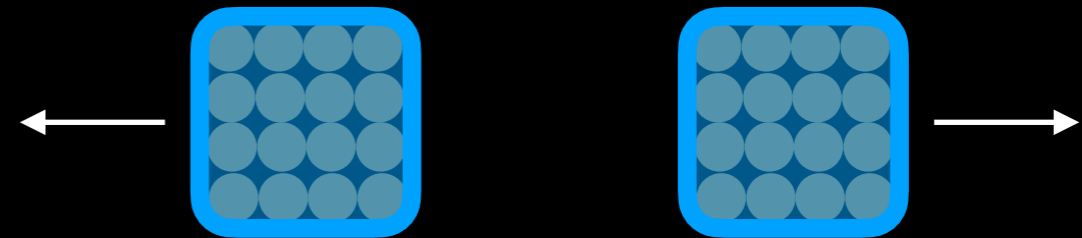
Two neutral bodies do not
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The nature of electricity ...

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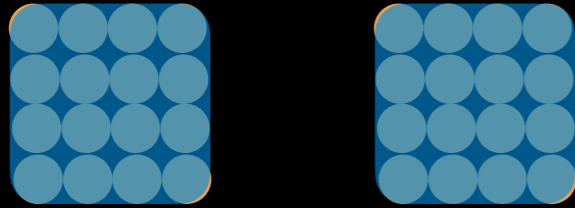
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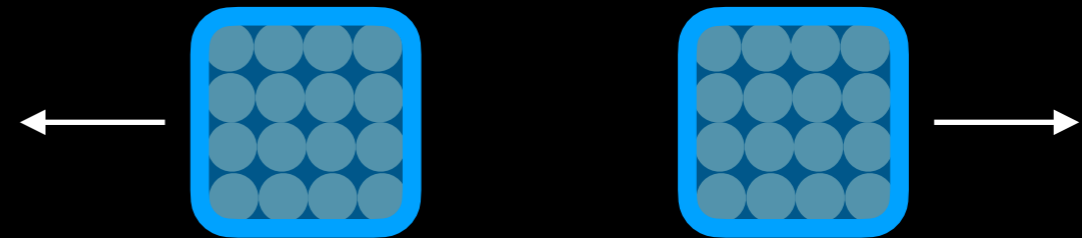
The atmospheres of two (positively) electrified bodies repel

The nature of electricity ...

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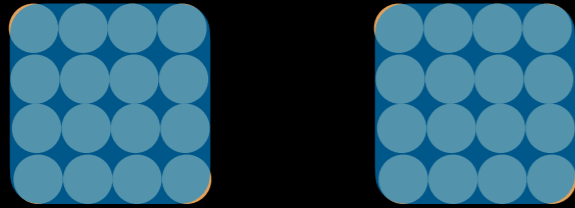


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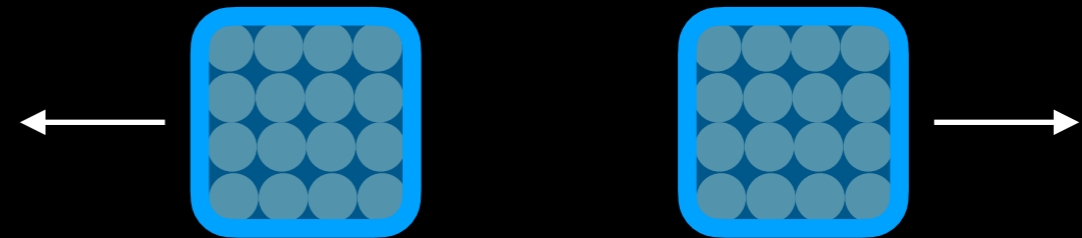
Franklin also worries about “action at a distance”:

The nature of electricity ...

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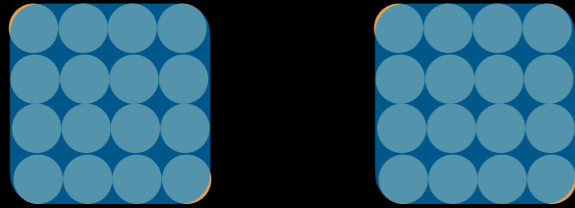
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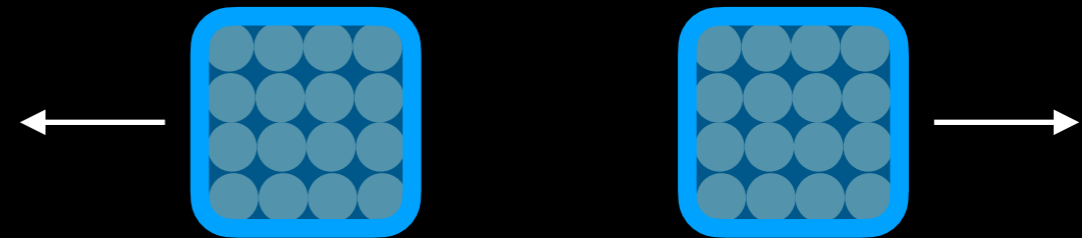
“It seems absurd to suppose that a body can act where it is not.”

The nature of electricity ...

... according to Benjamin Franklin



Two neutral bodies do not attract nor repel



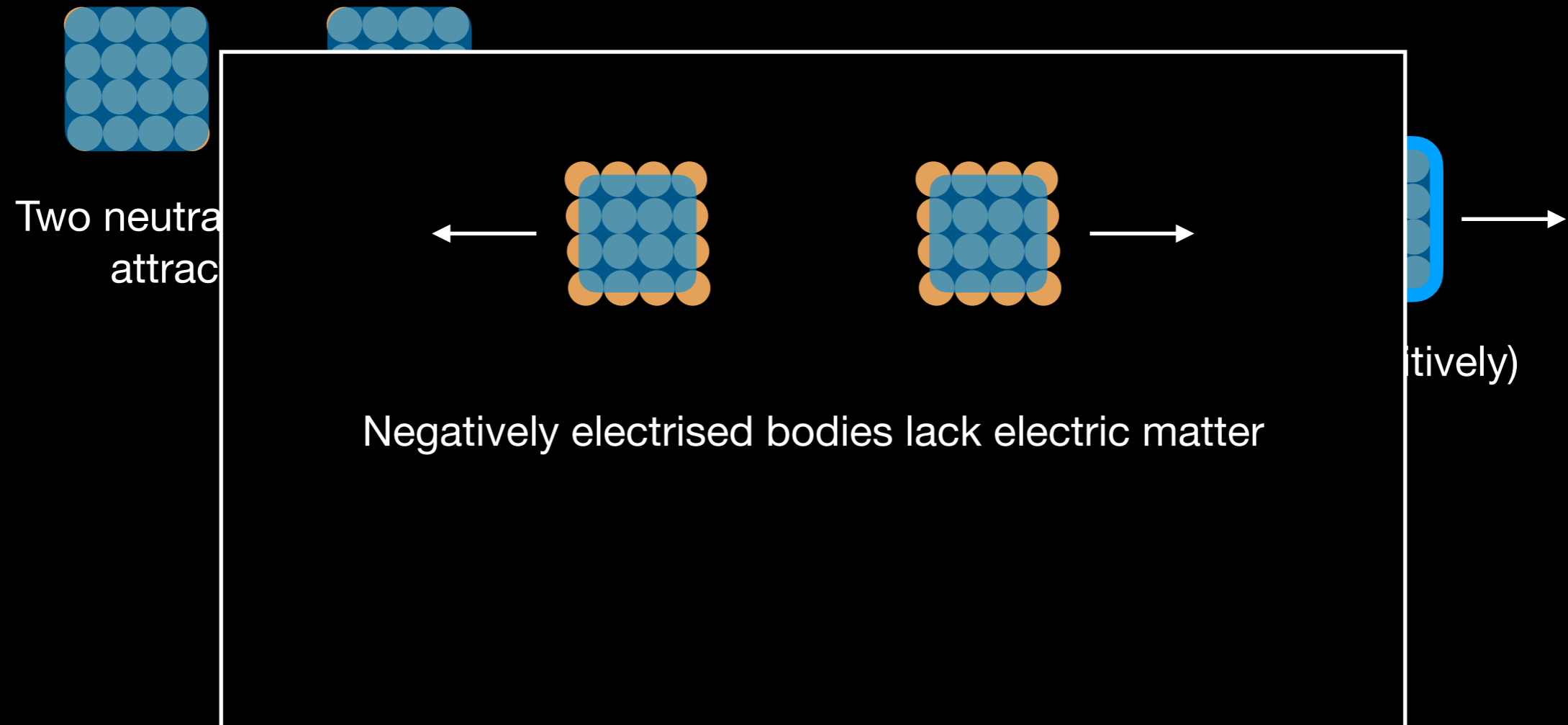
The atmospheres of two (positively) electrified bodies repel

Franklin also worries about “action at a distance”:

“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 ...

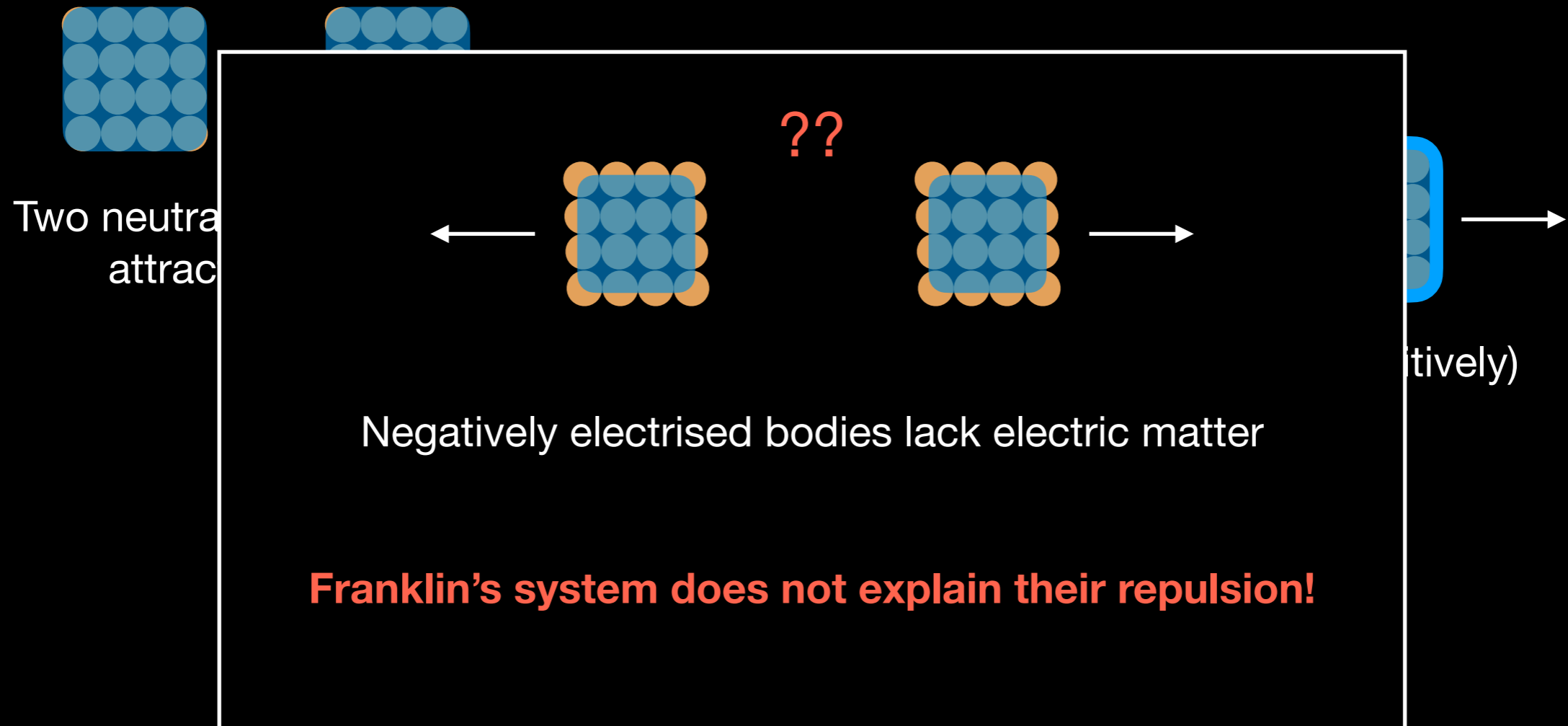
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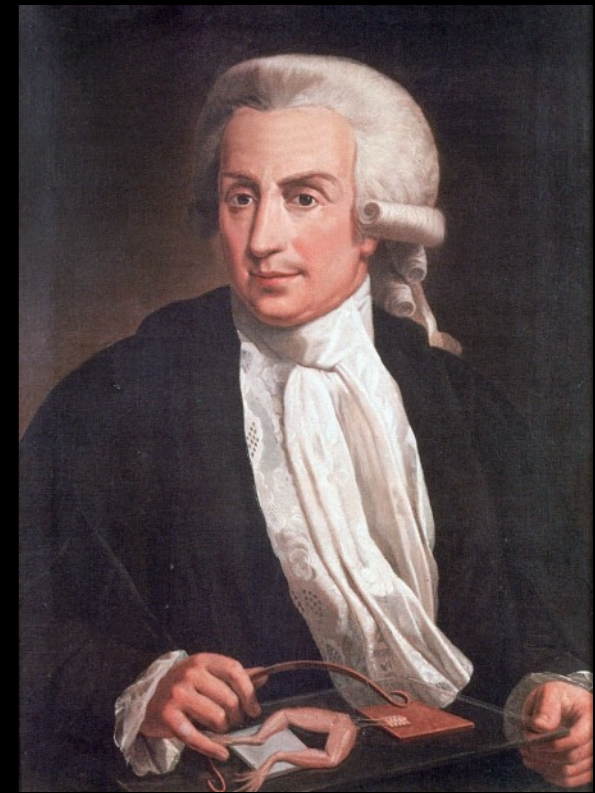
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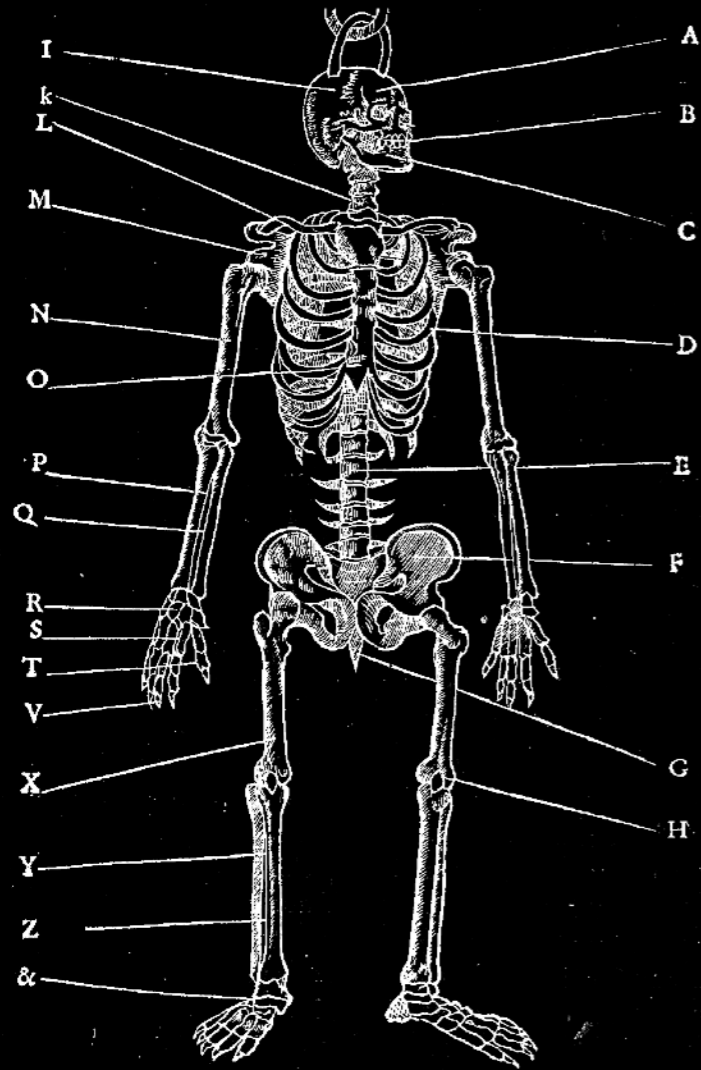
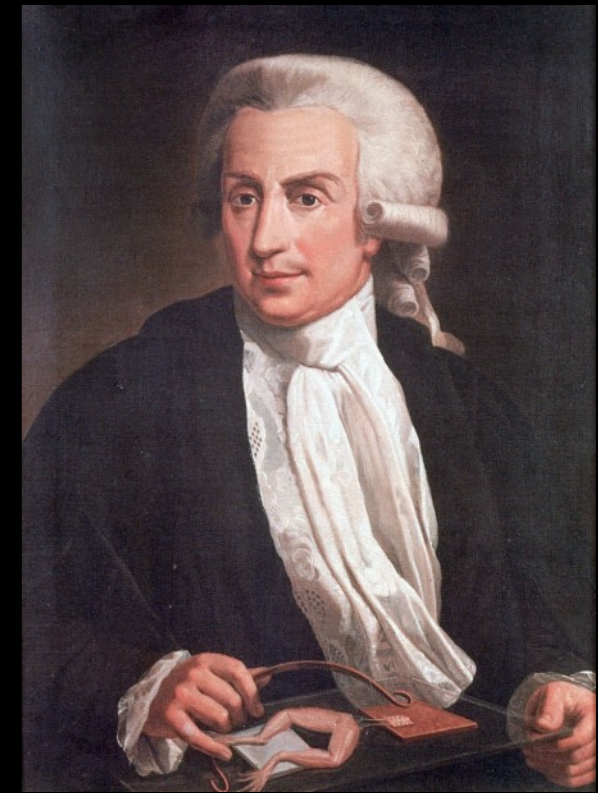
Luigi Galvani

Anatomist, lecturer at University of Bologna



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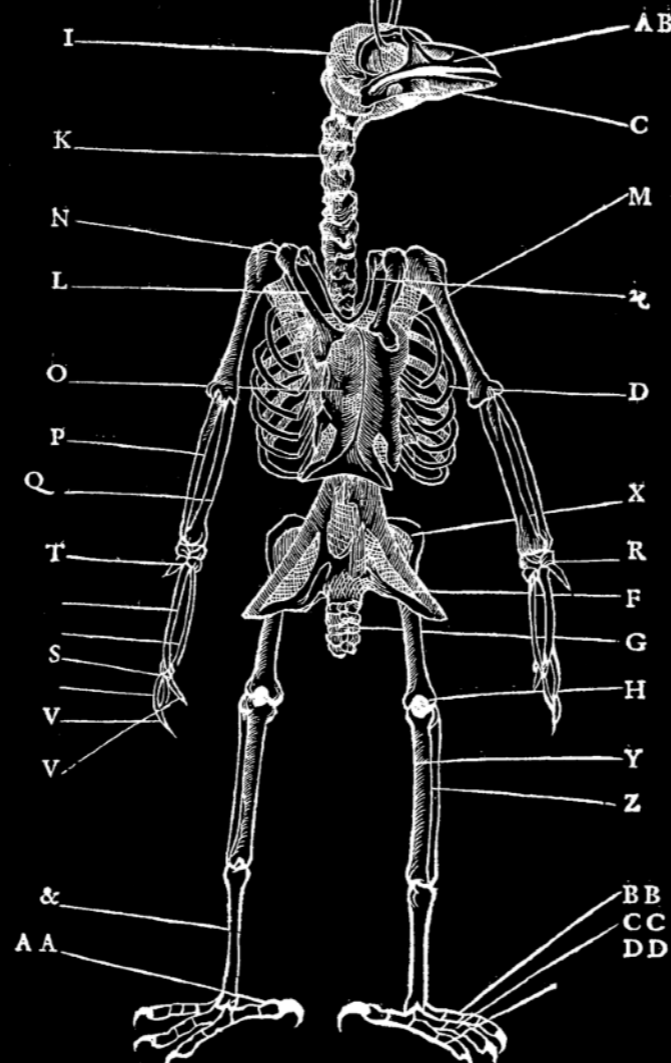
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Human



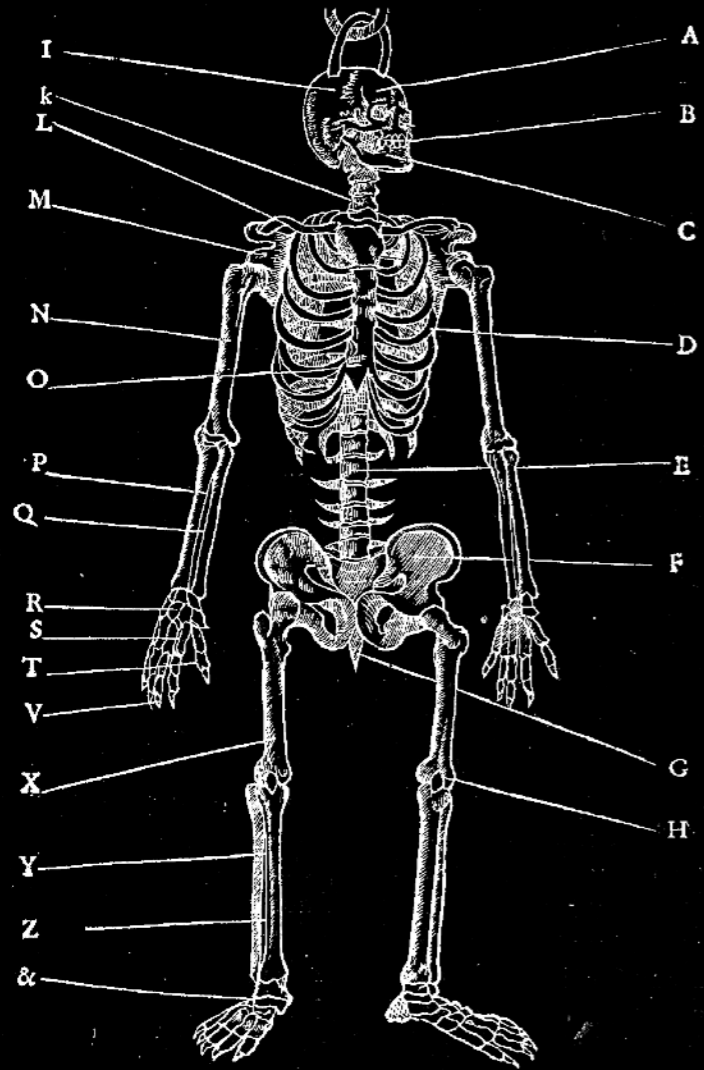
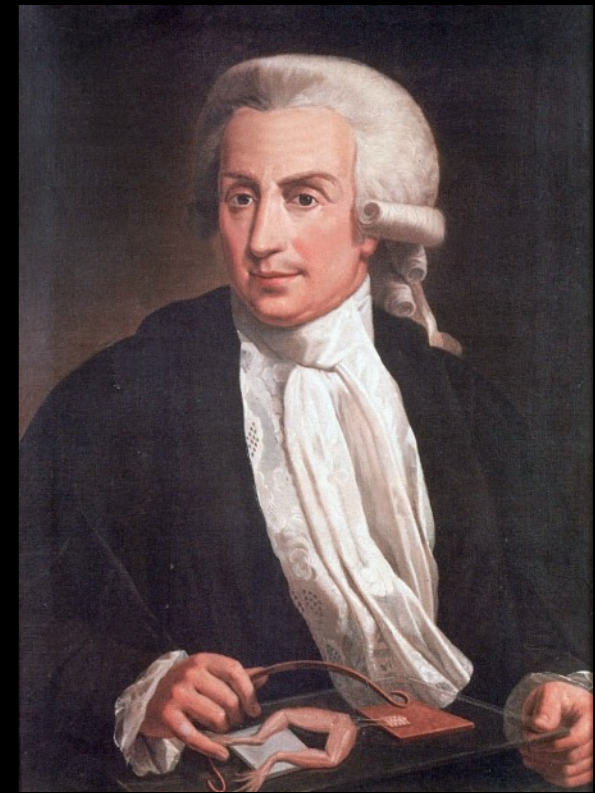
Bird



“Comparative anatomy”

Luigi Galvani

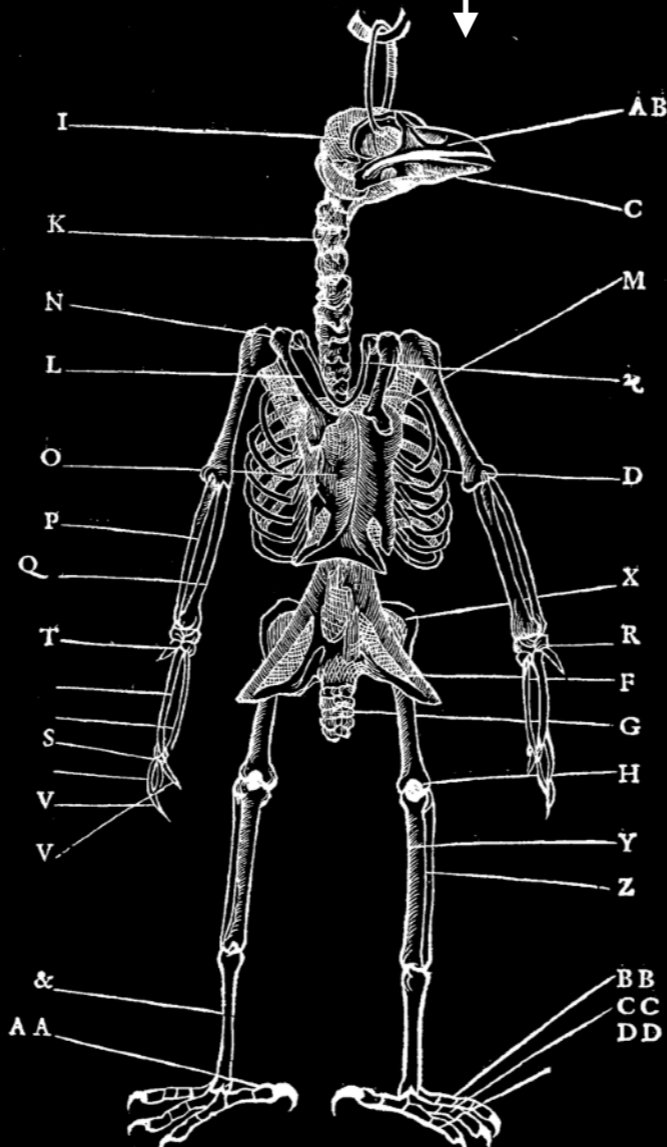
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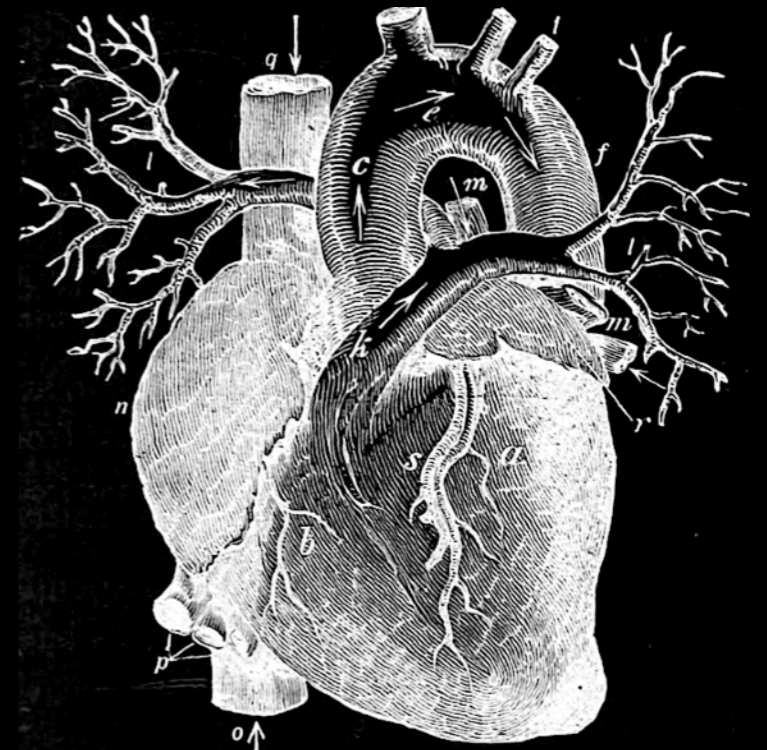
Human



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“Comparative anatomy”

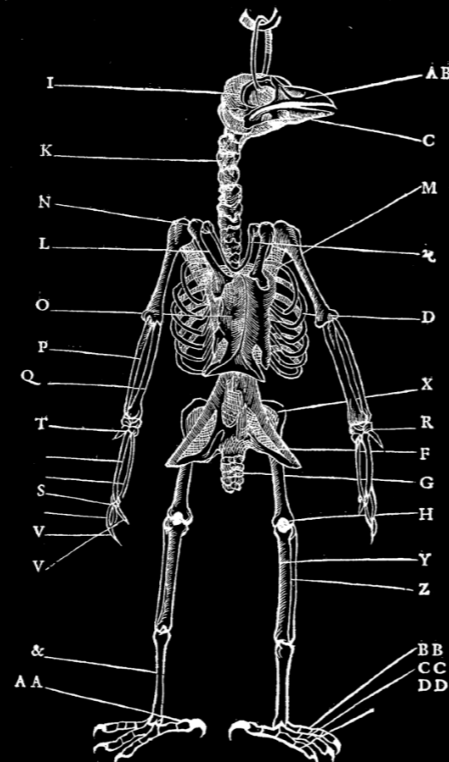
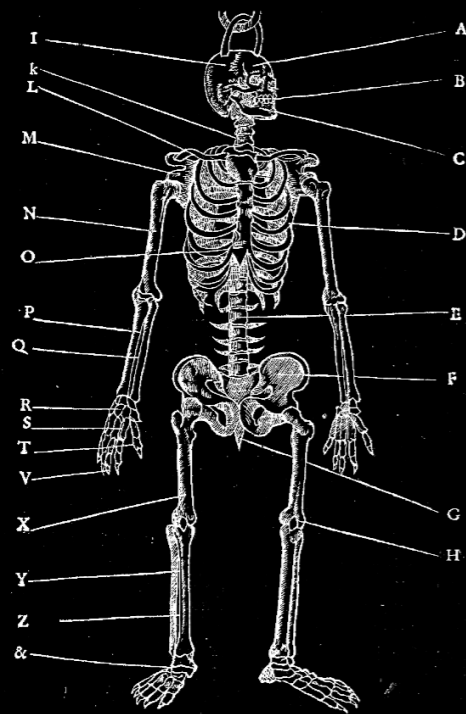


Physiology

Frogs and “animal electricity”

1791:

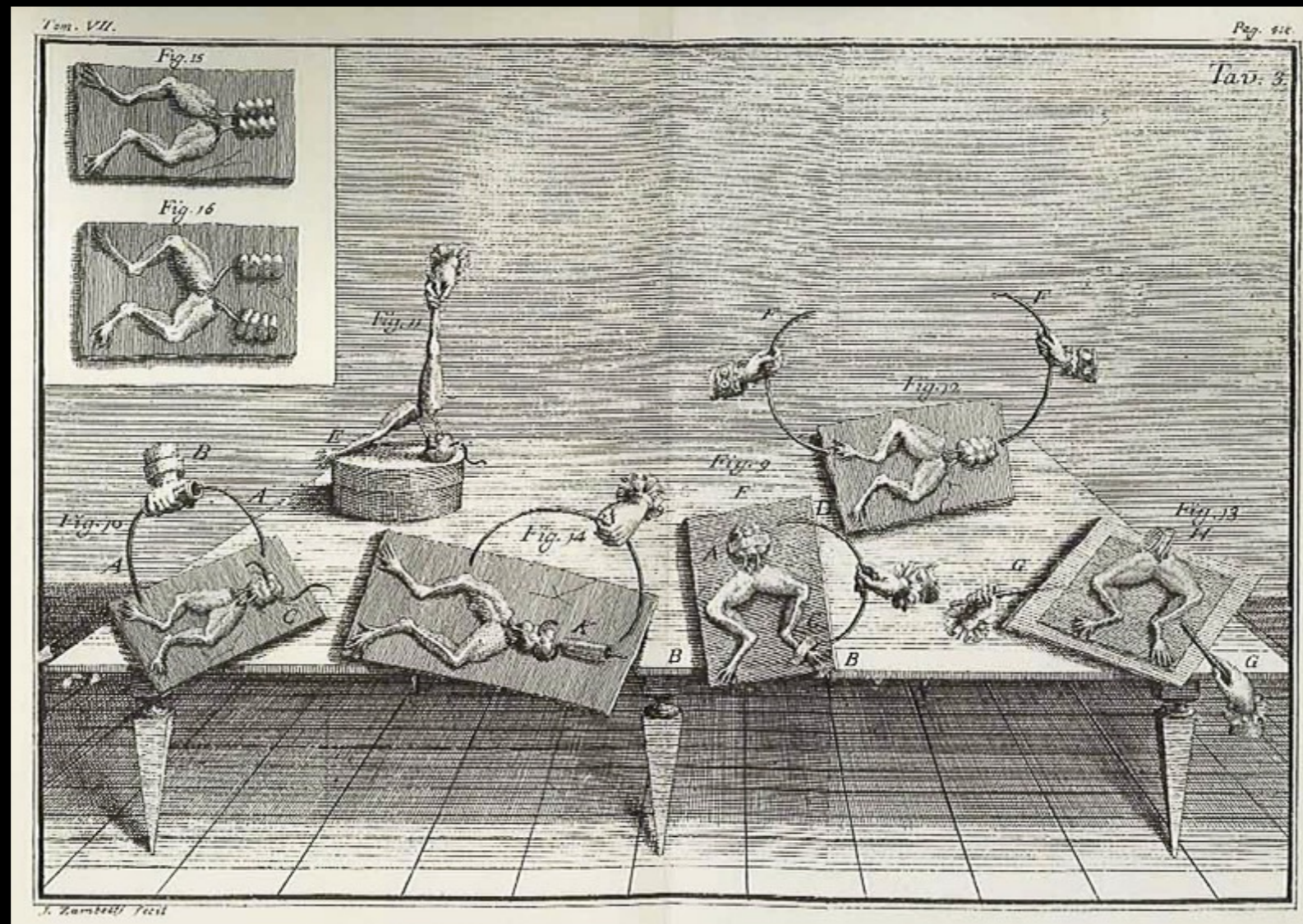
“Prepared frogs, which were fastened by brass hooks in their spinal cord to an iron railing which surrounded a certain hanging garden of my house, fell into contractions.”



Frogs and “animal electricity”

Galvani tries a more controlled experiment:

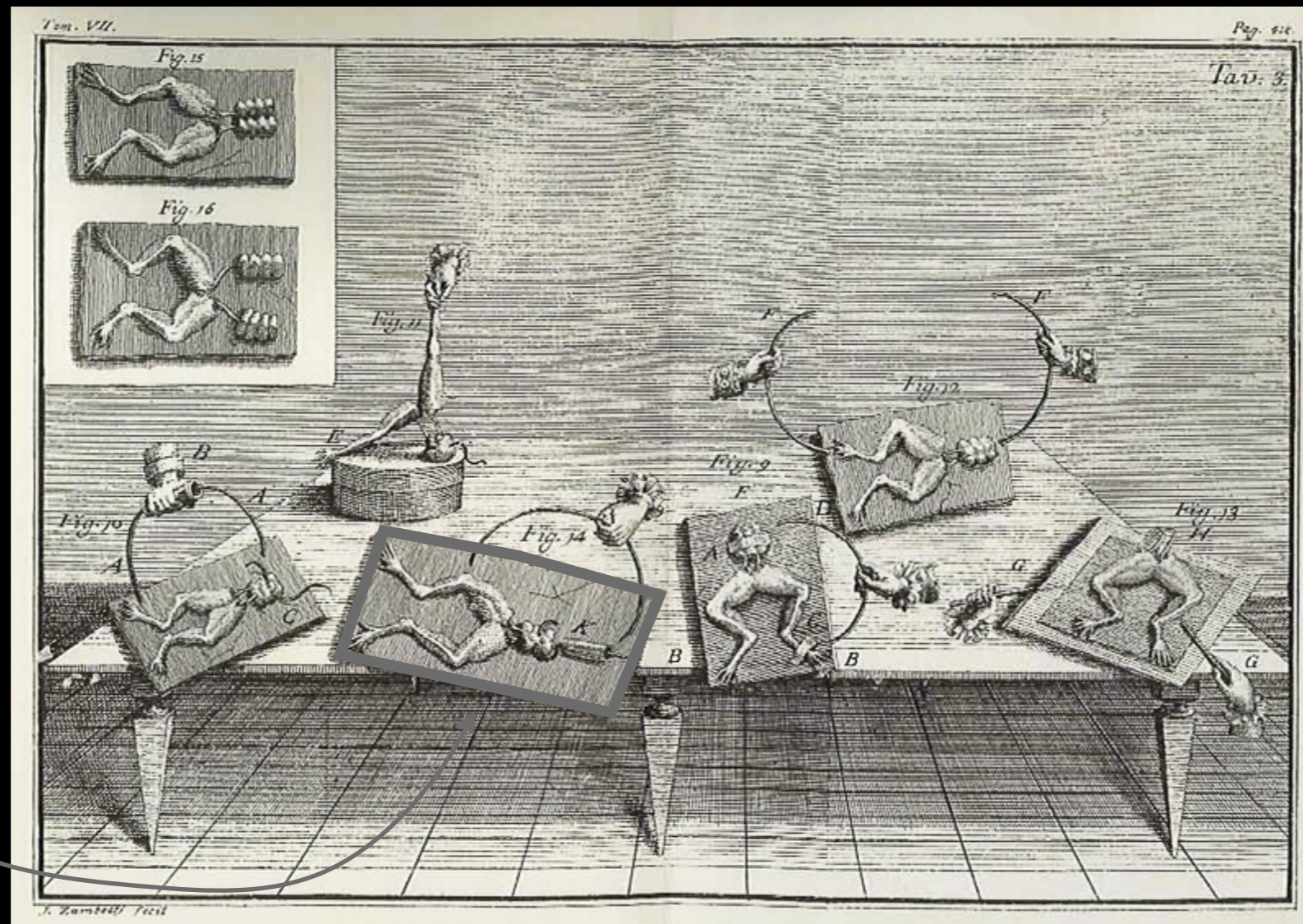
“When I brought the animal into a closed room, placed it on an iron plate, and began to press the hook with which it was fastened in the spinal cord against the plate, Behold!, the same contractions occurred as before.”



Frogs and “animal electricity”

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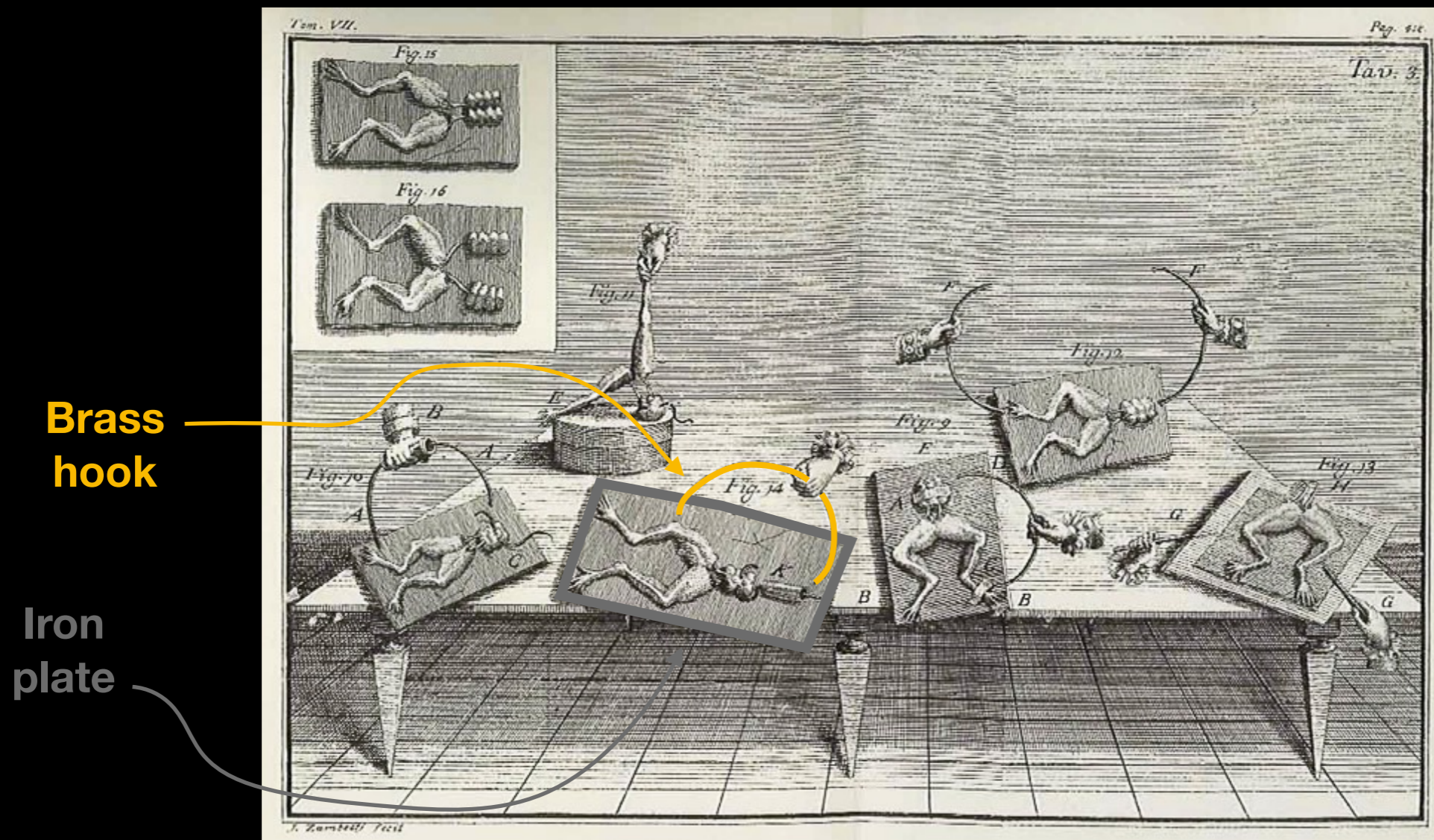


Iron plate

Frogs and “animal electricity”

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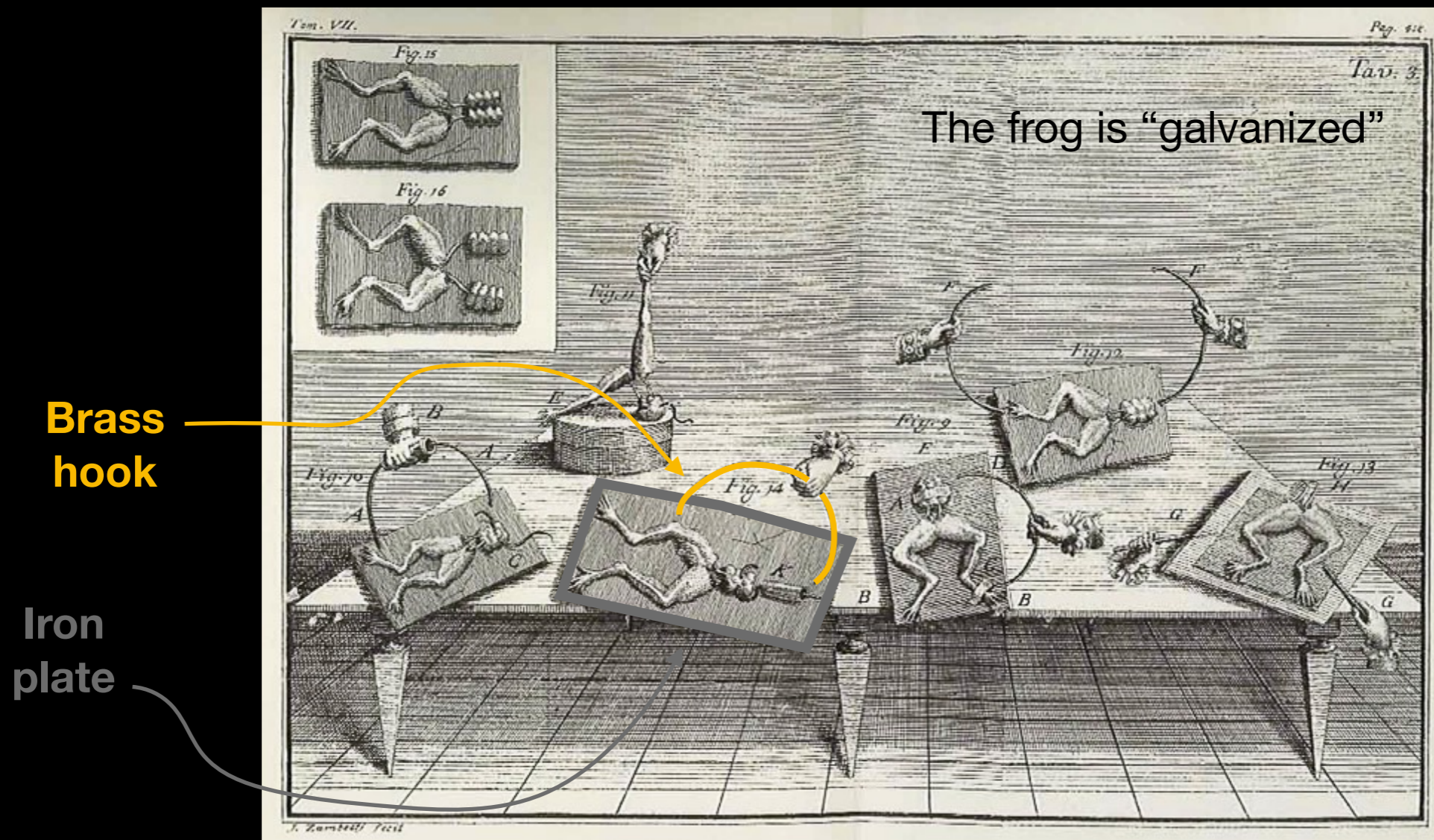
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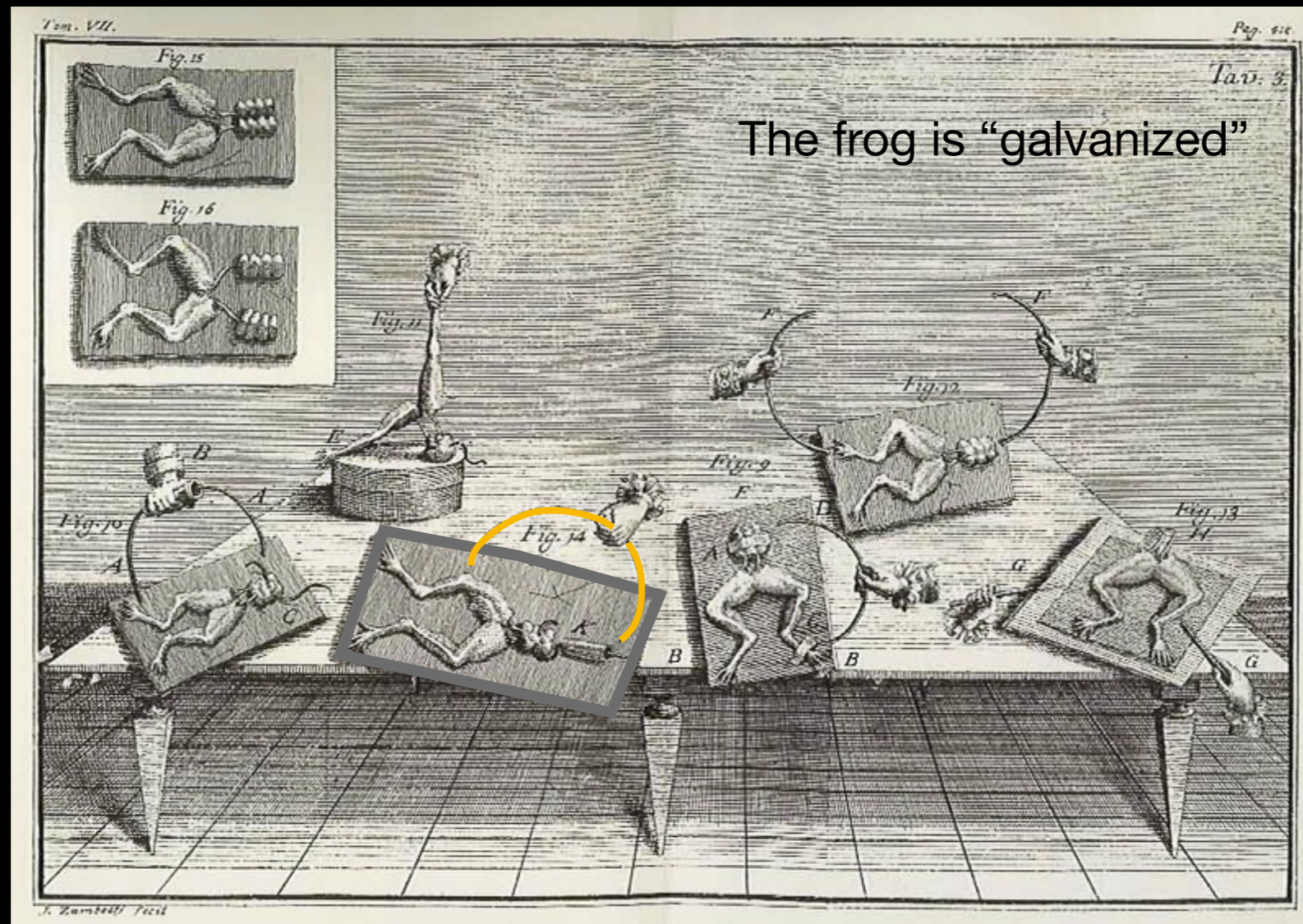
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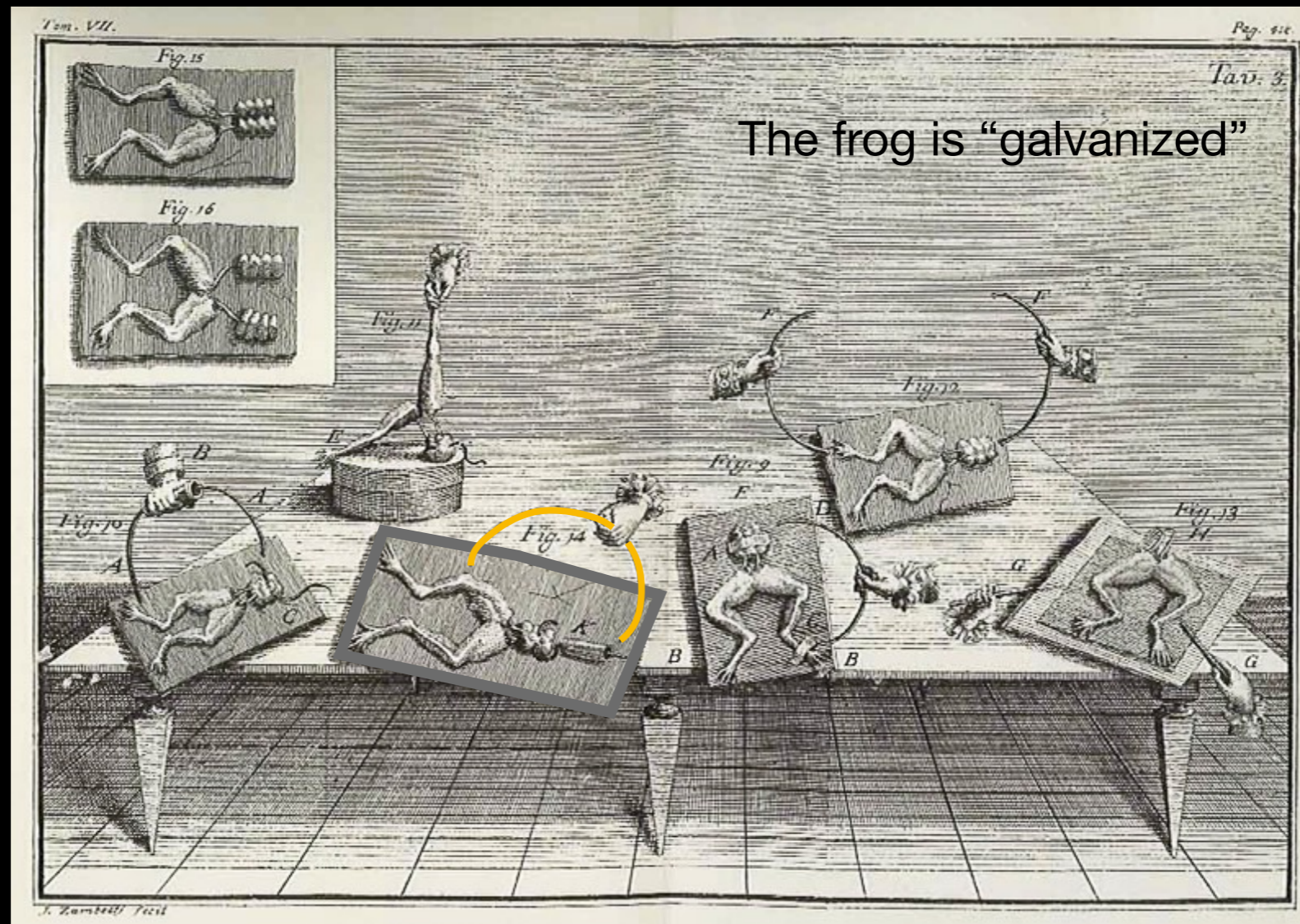
“I immediately repeated the experiment in different places with different metals.”



Frogs and “animal electricity”

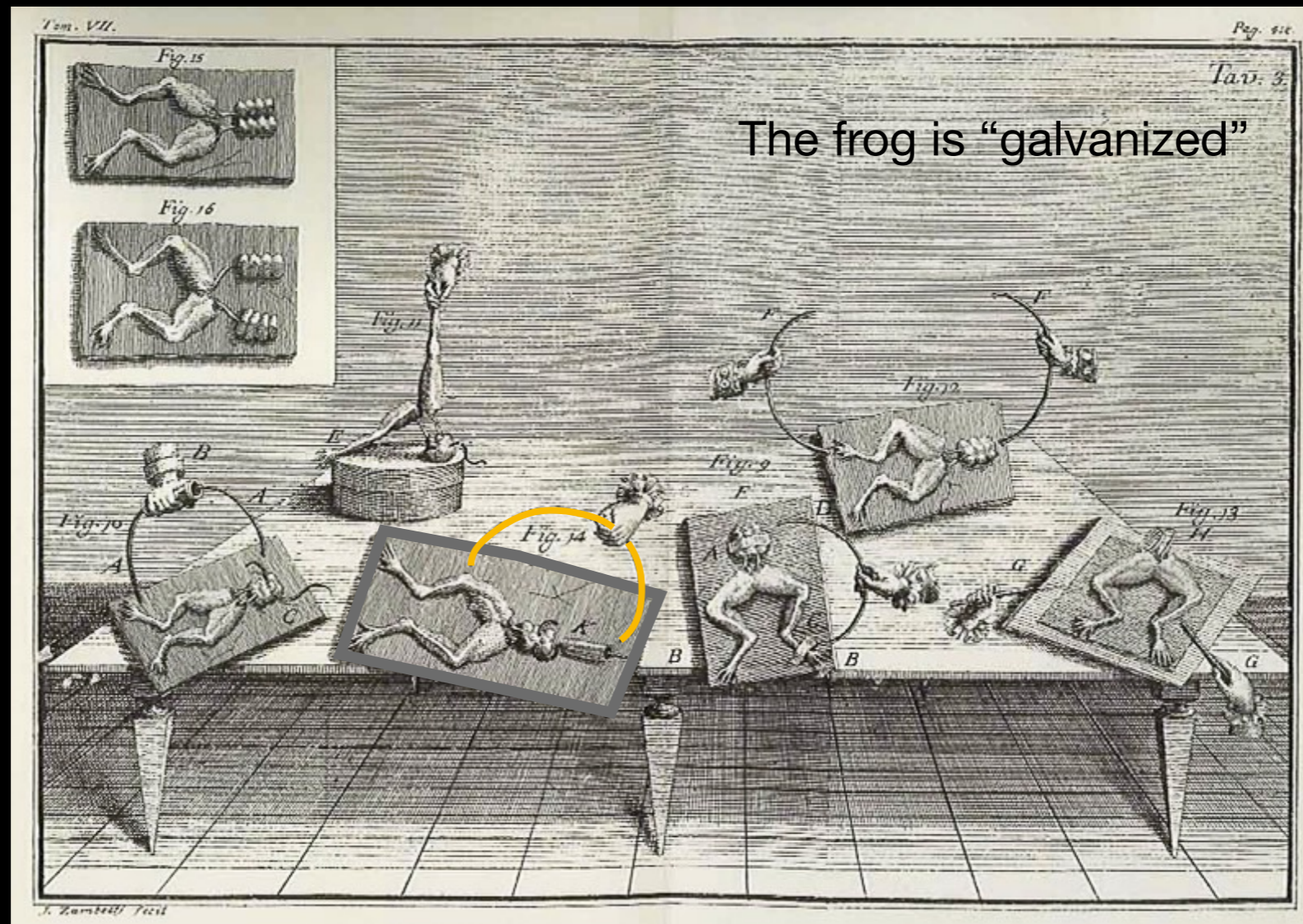
Galvani tries a more controlled experiment:

“I immediately repeated the experiment in different places with different metals. 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”

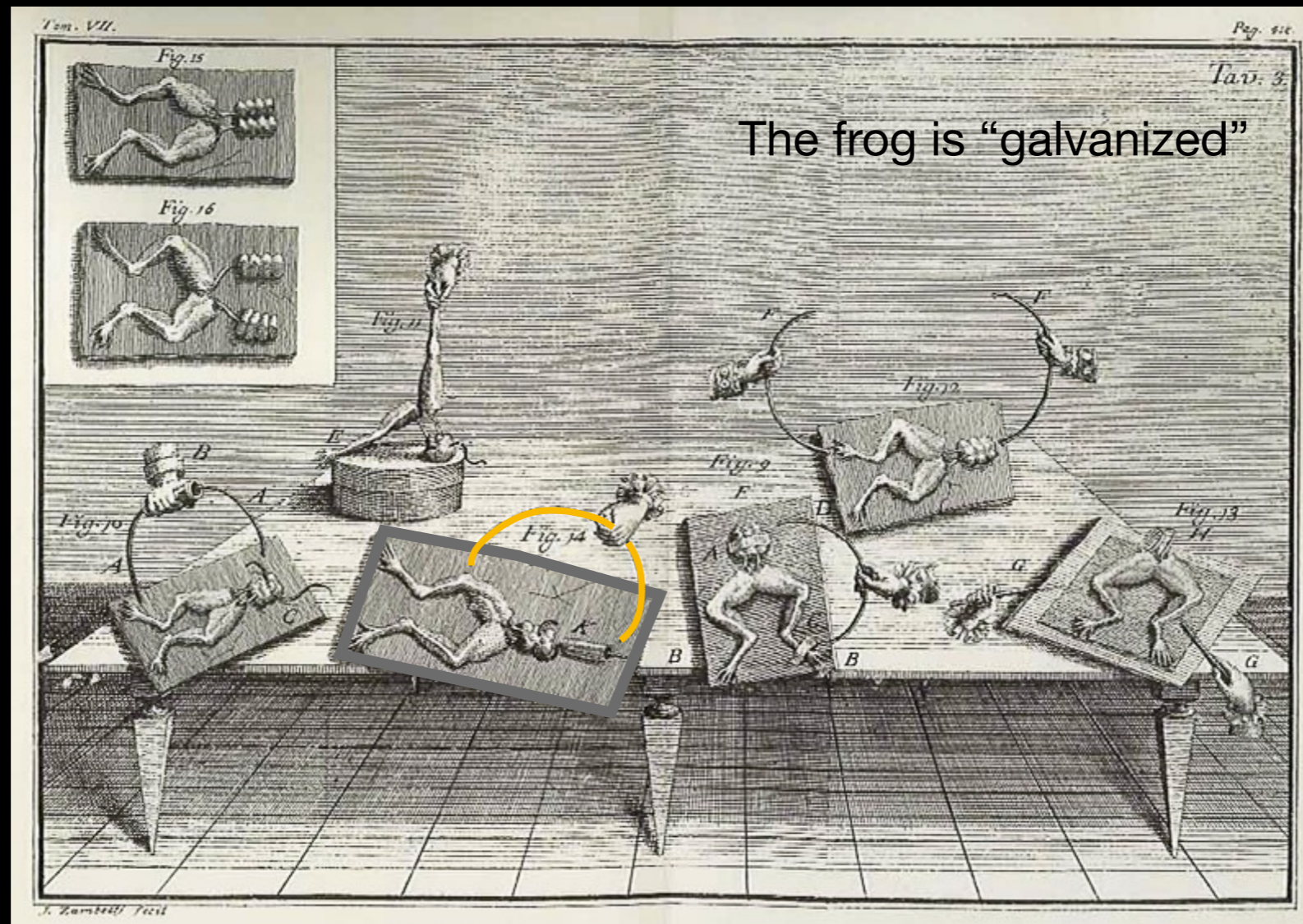
Galvani tries a more controlled experiment:



Frogs and “animal electricity”

Galvani tries a more controlled experiment:

“No muscular contractions or movements were evident when using non-conductors or very poor conductors of electricity, like glass, gum, resin, and stones.”



Frogs and “animal electricity”

His conclusions (1791):

Frogs and “animal electricity”

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

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Frogs and “animal electricity”

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Frogs and “animal electricity”

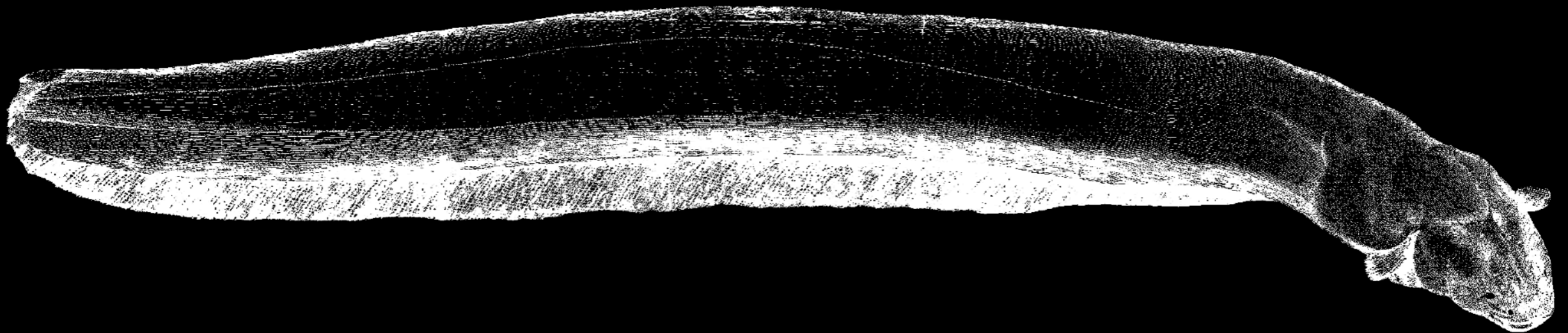
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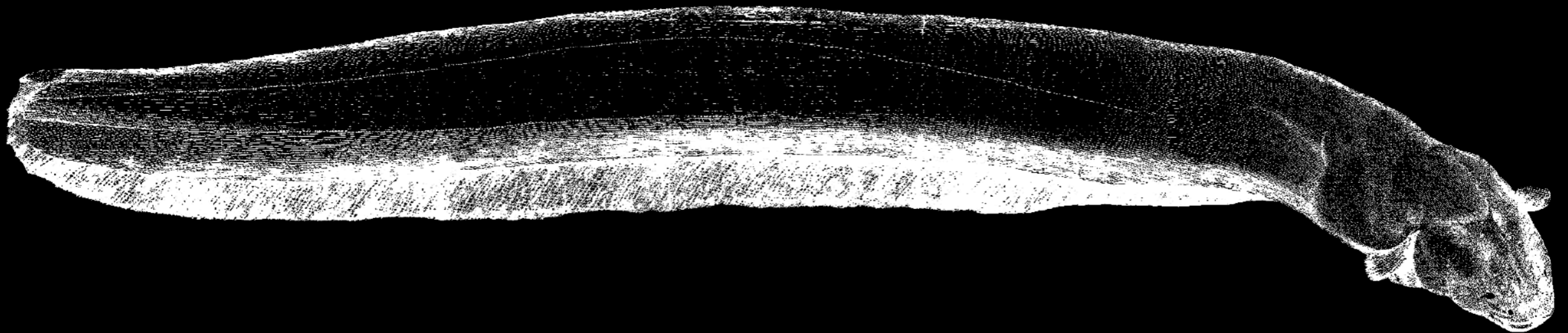
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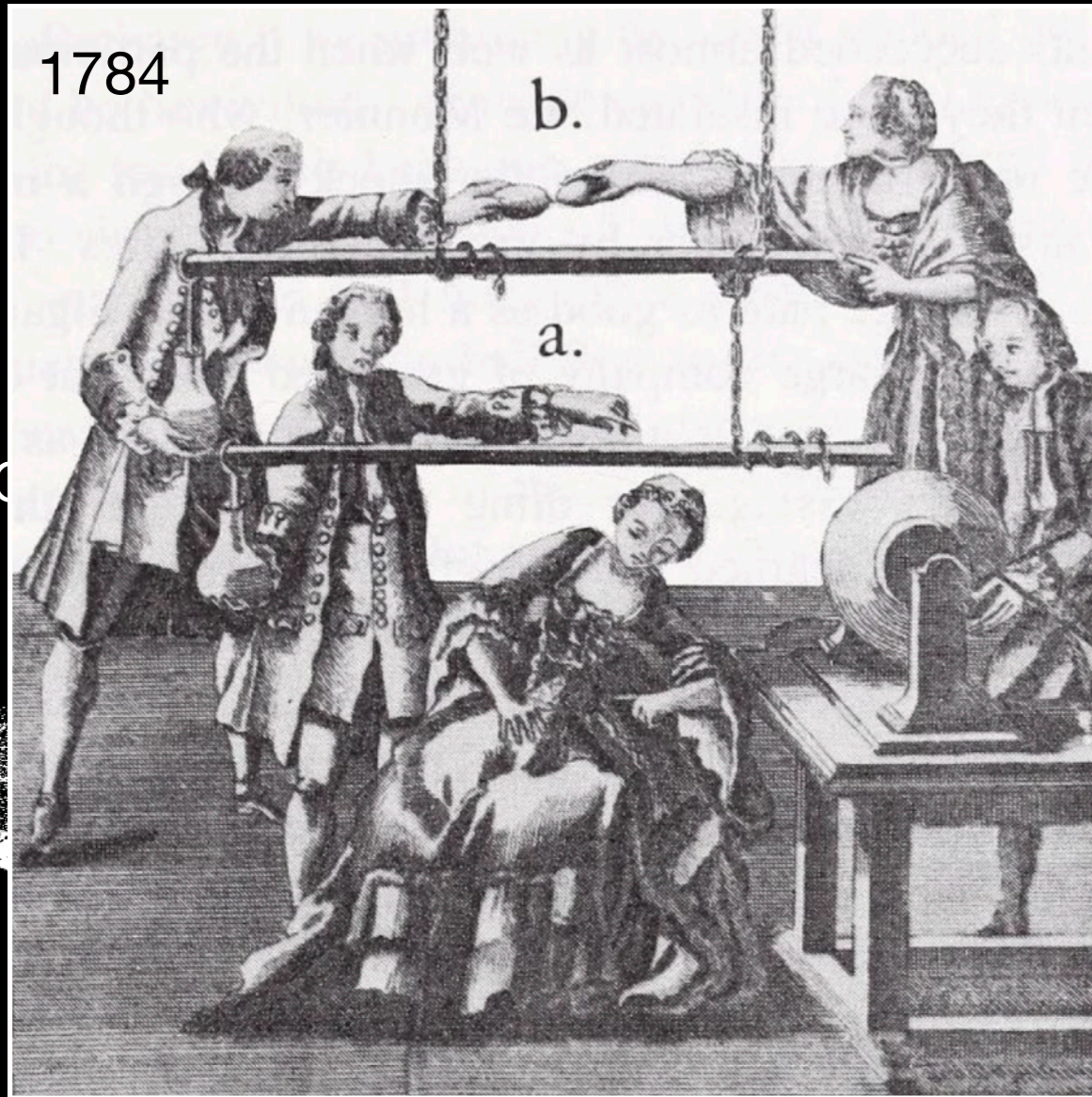


But: *“contractions varied with the metals used”*

Frogs and “animal electricity”

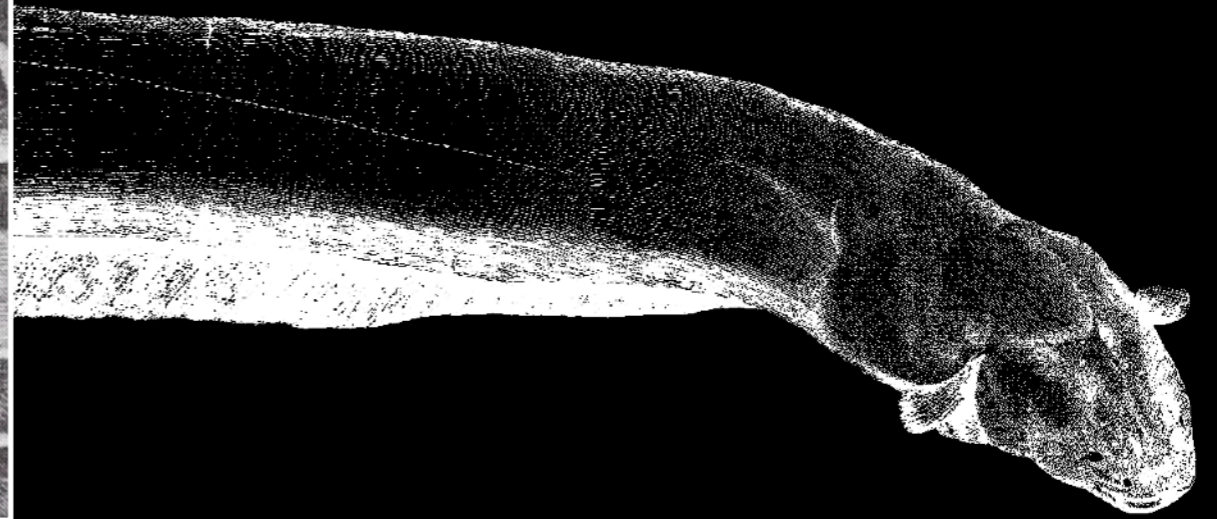
His conclusions (1791):

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“... a delicate nerve fluid is made from the phenomenon of the contractions is produced, is completed in a Leyden jar [...]”

→ “Animal electricity”



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

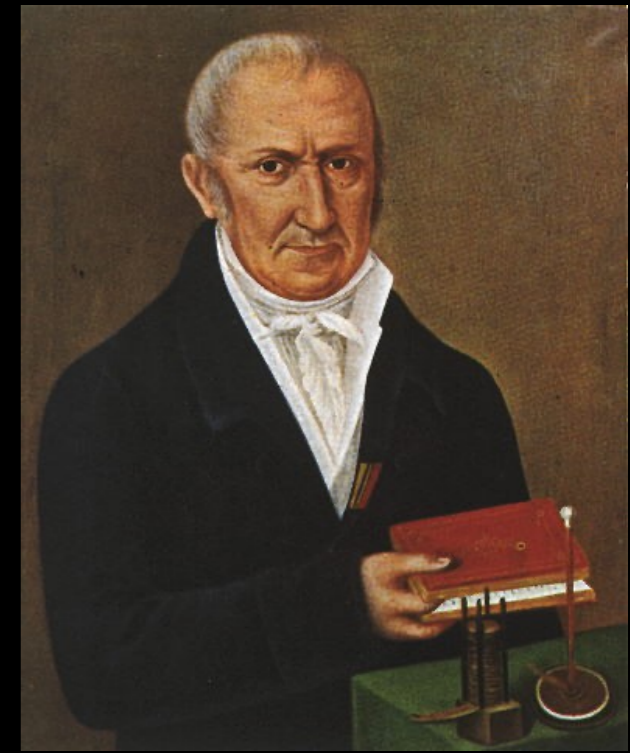
Volta's opposition



Alessandro Volta

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In a letter, May 1793:



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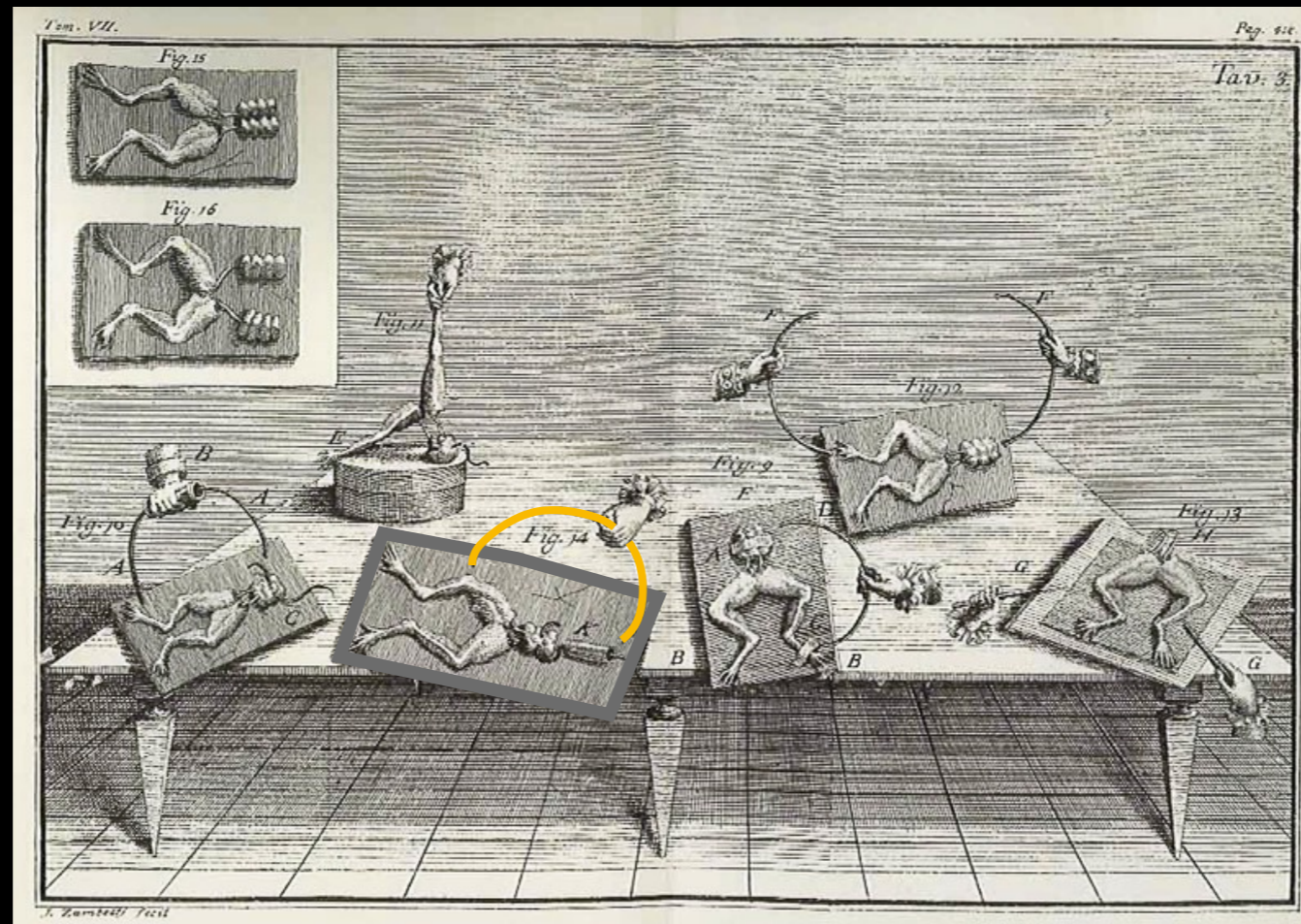
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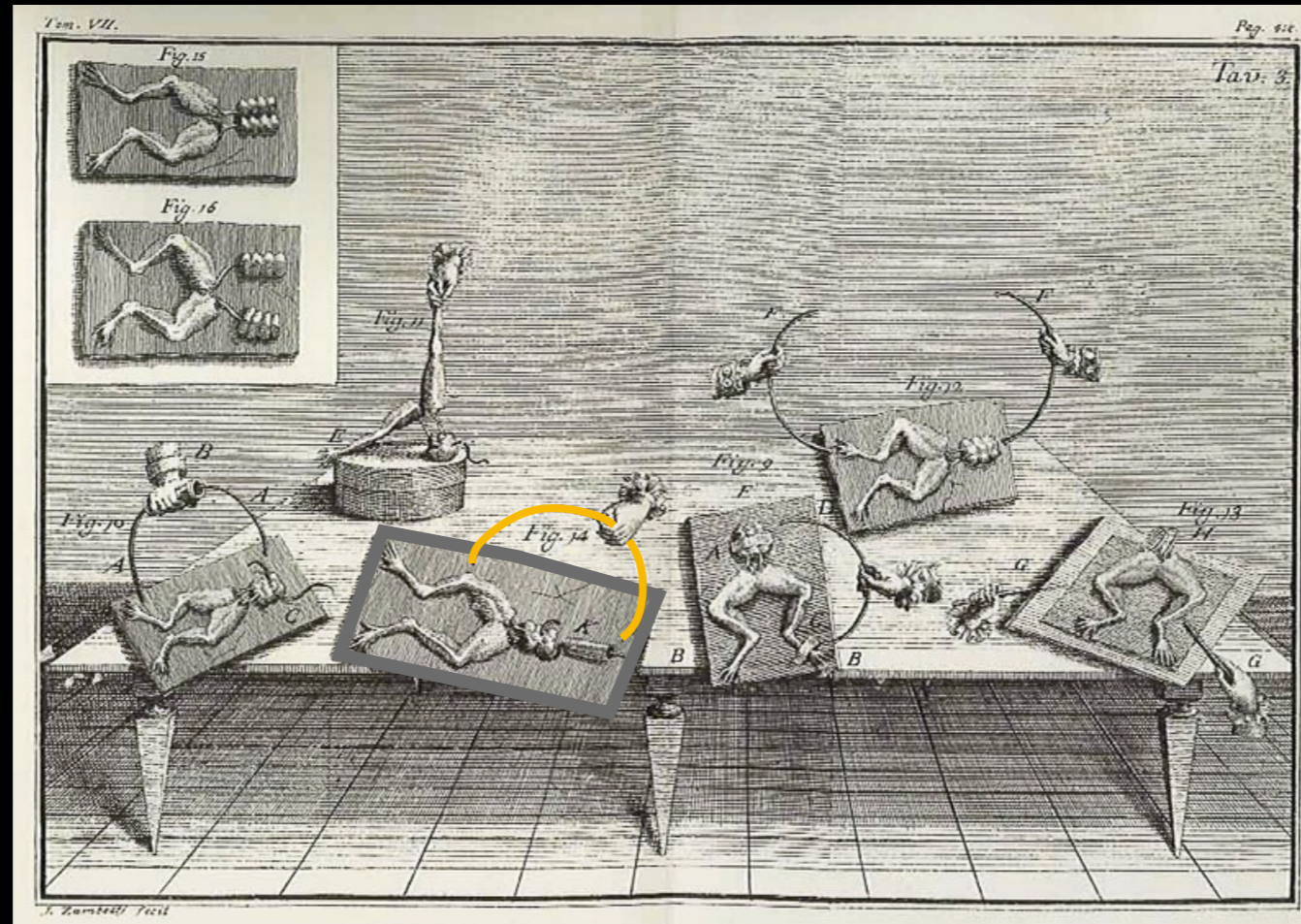
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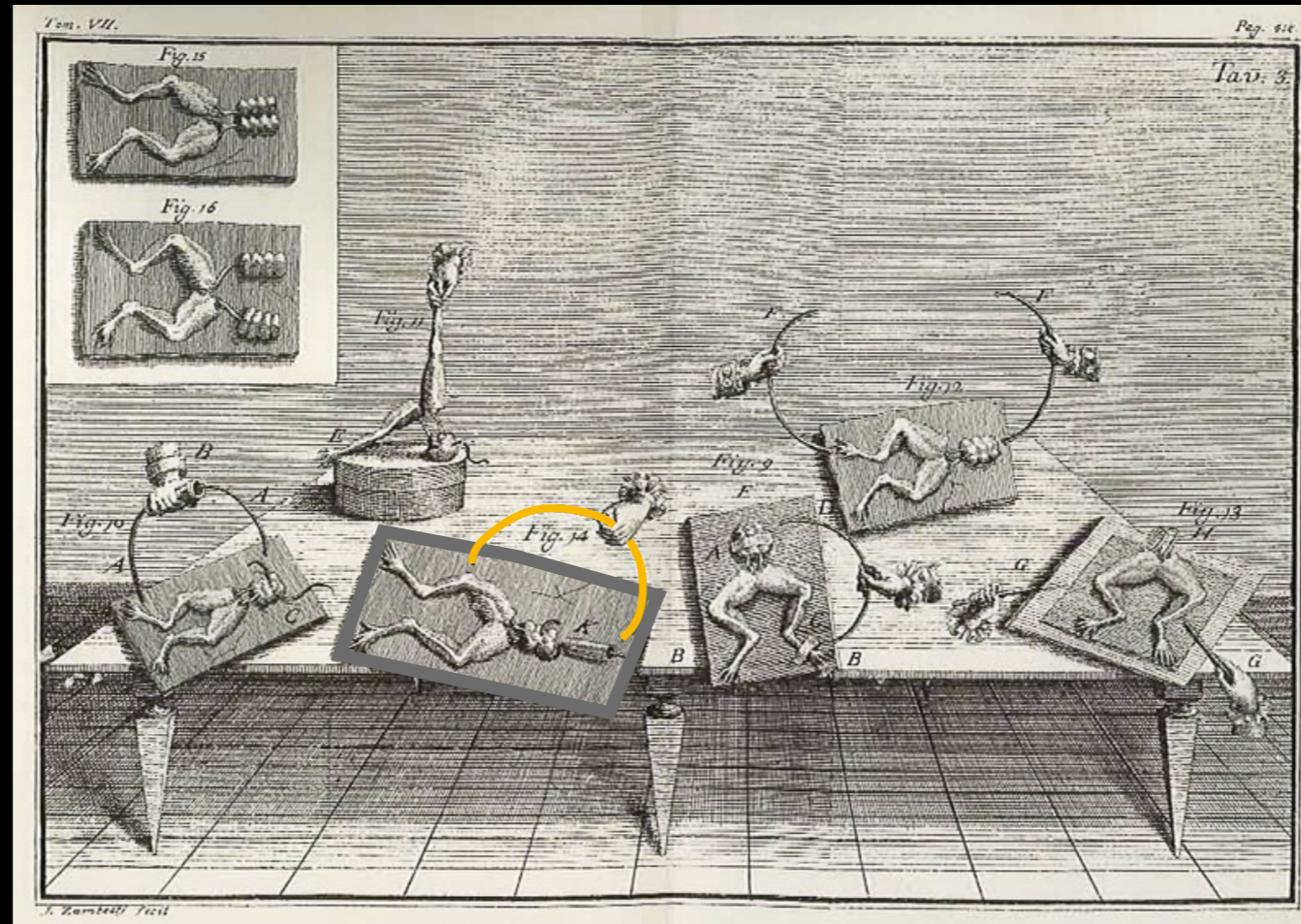
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Galvani's frogs merely supply some “wet substance”!

Volta's "artificial electric organ"

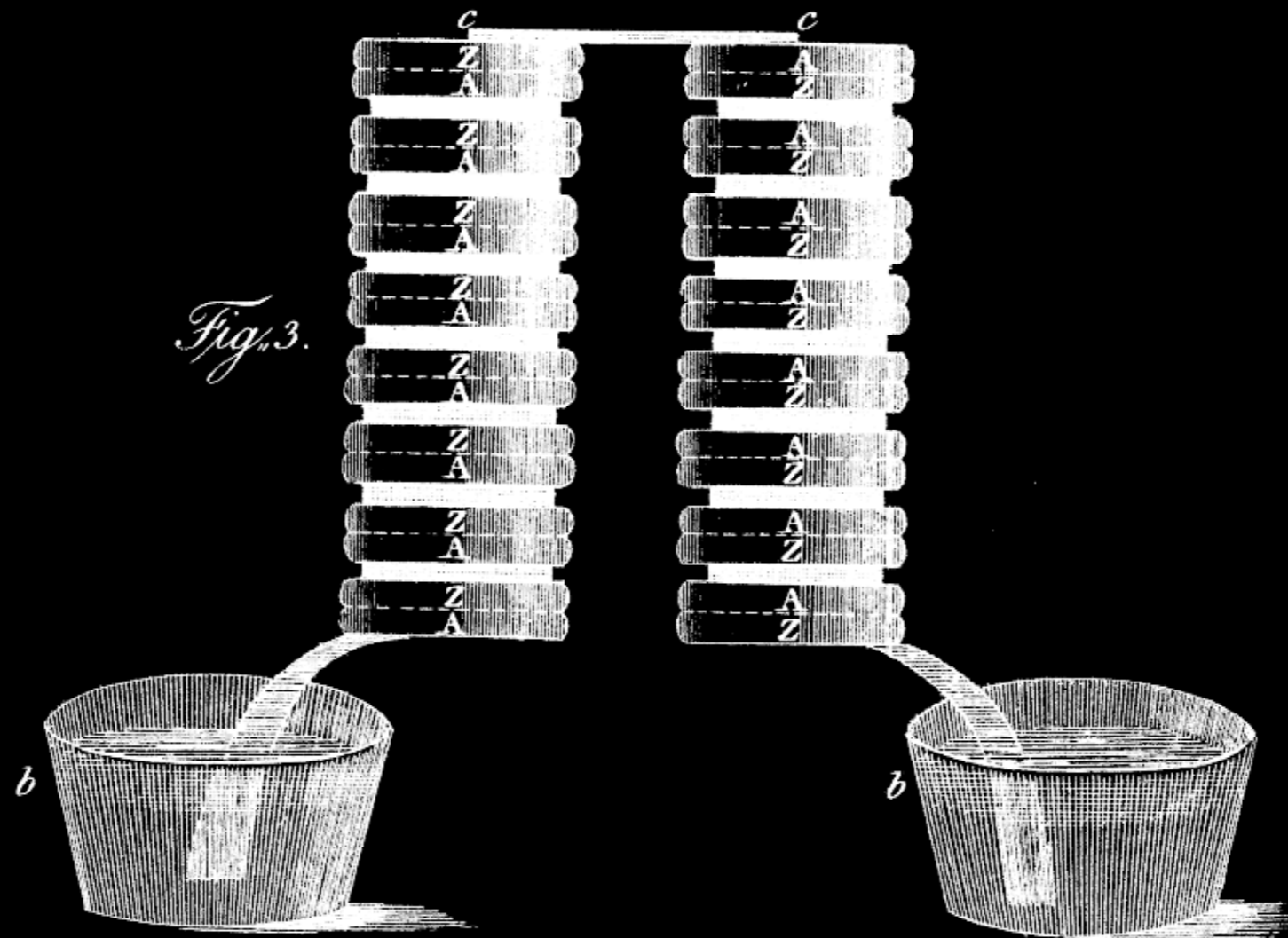
In a letter to the Royal Society, March 1800:

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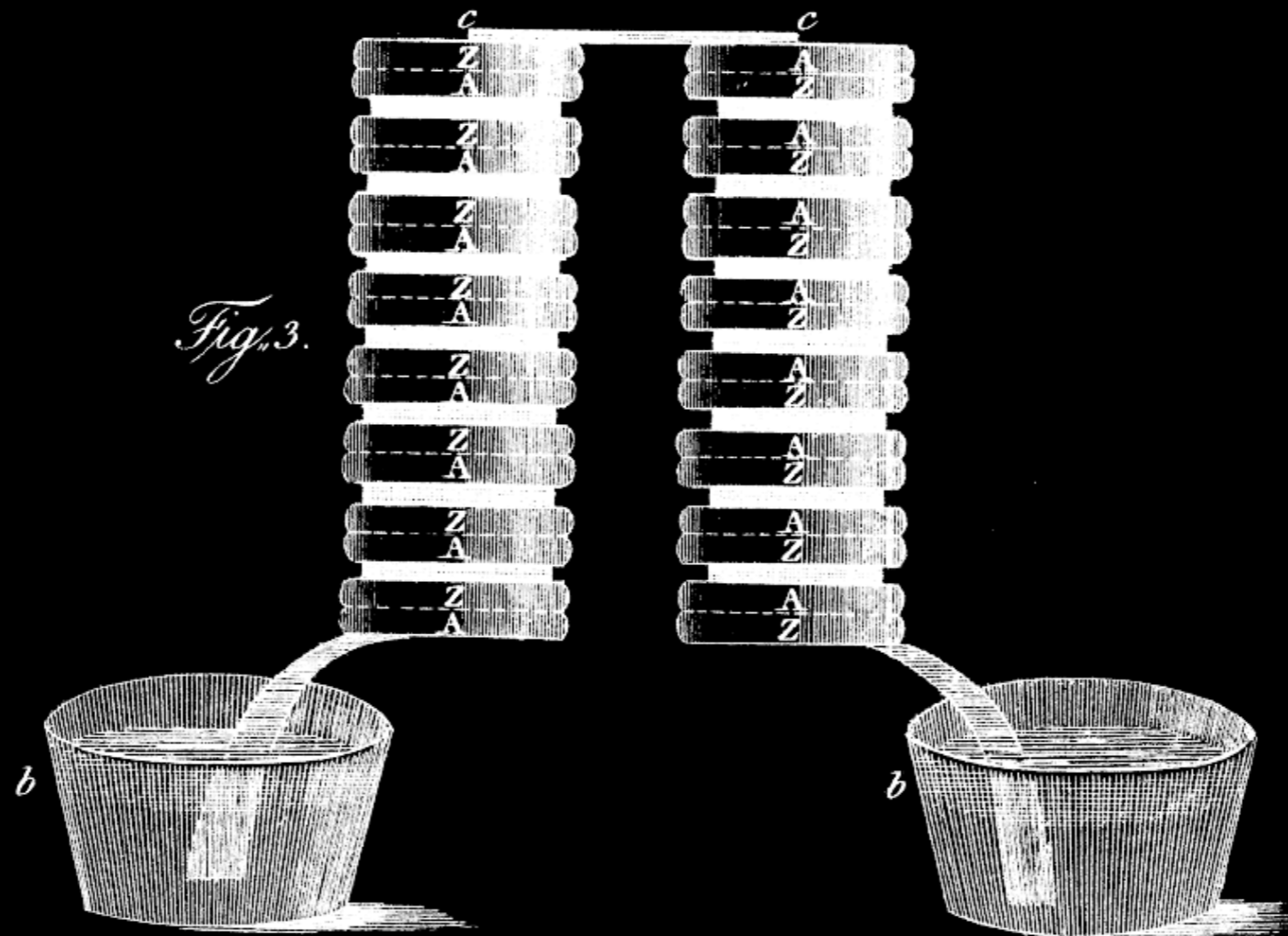
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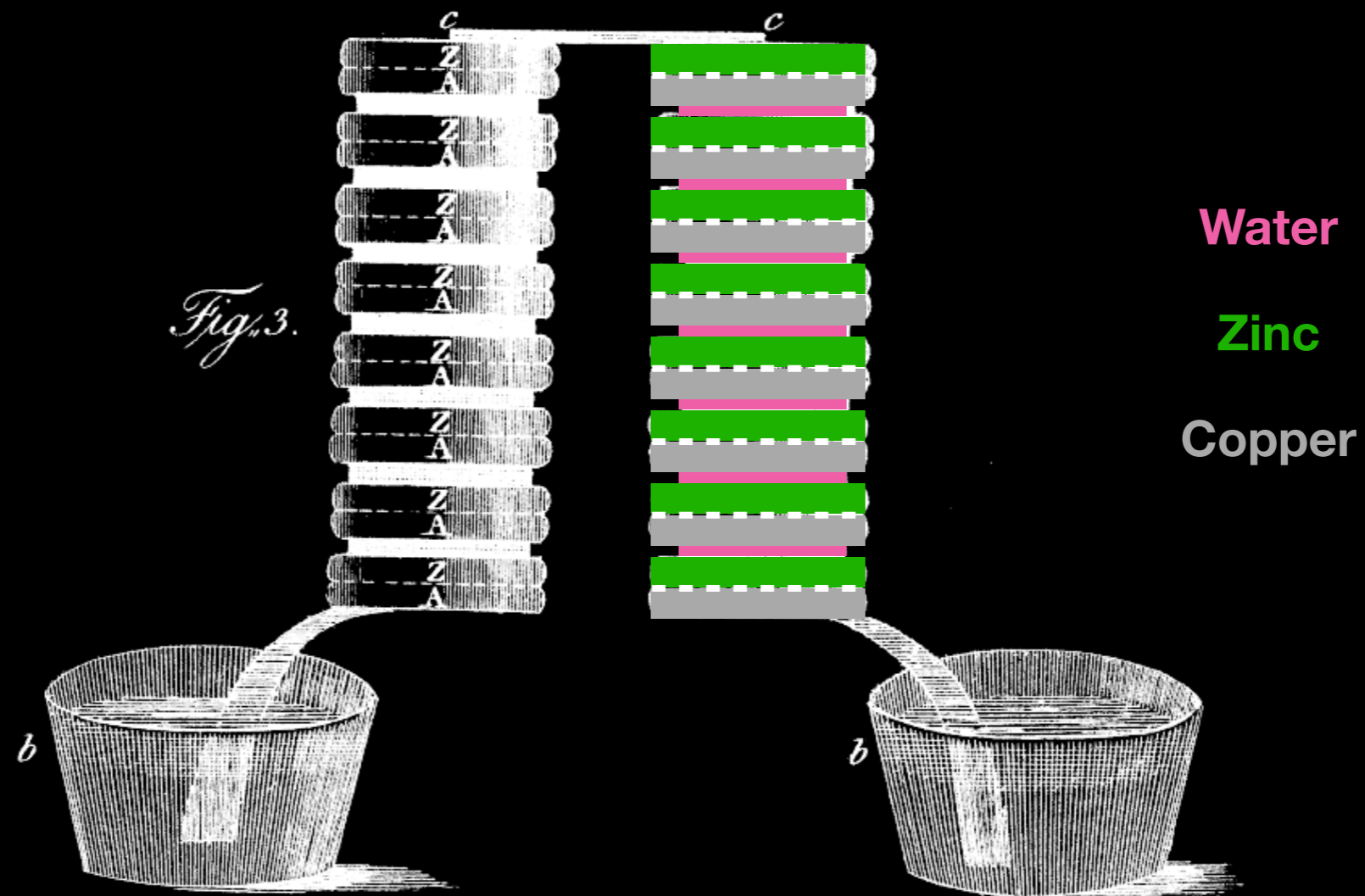
"Thirty, forty, sixty or more pieces of copper, applied each to a piece of zinc, and as many pieces of pasteboard, well soaked in water; such strata interposed between every pair of two different metals in an alternate series."



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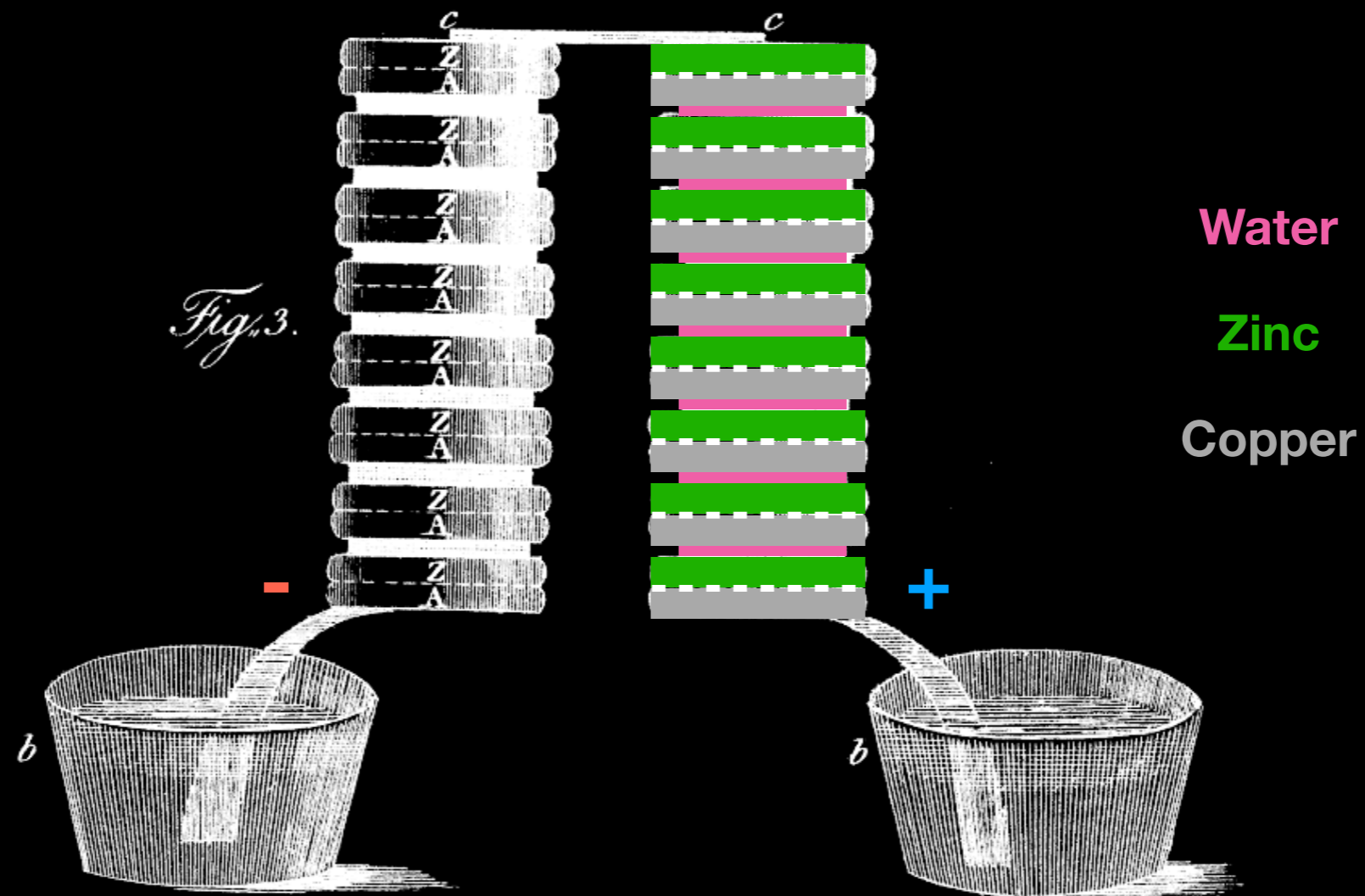
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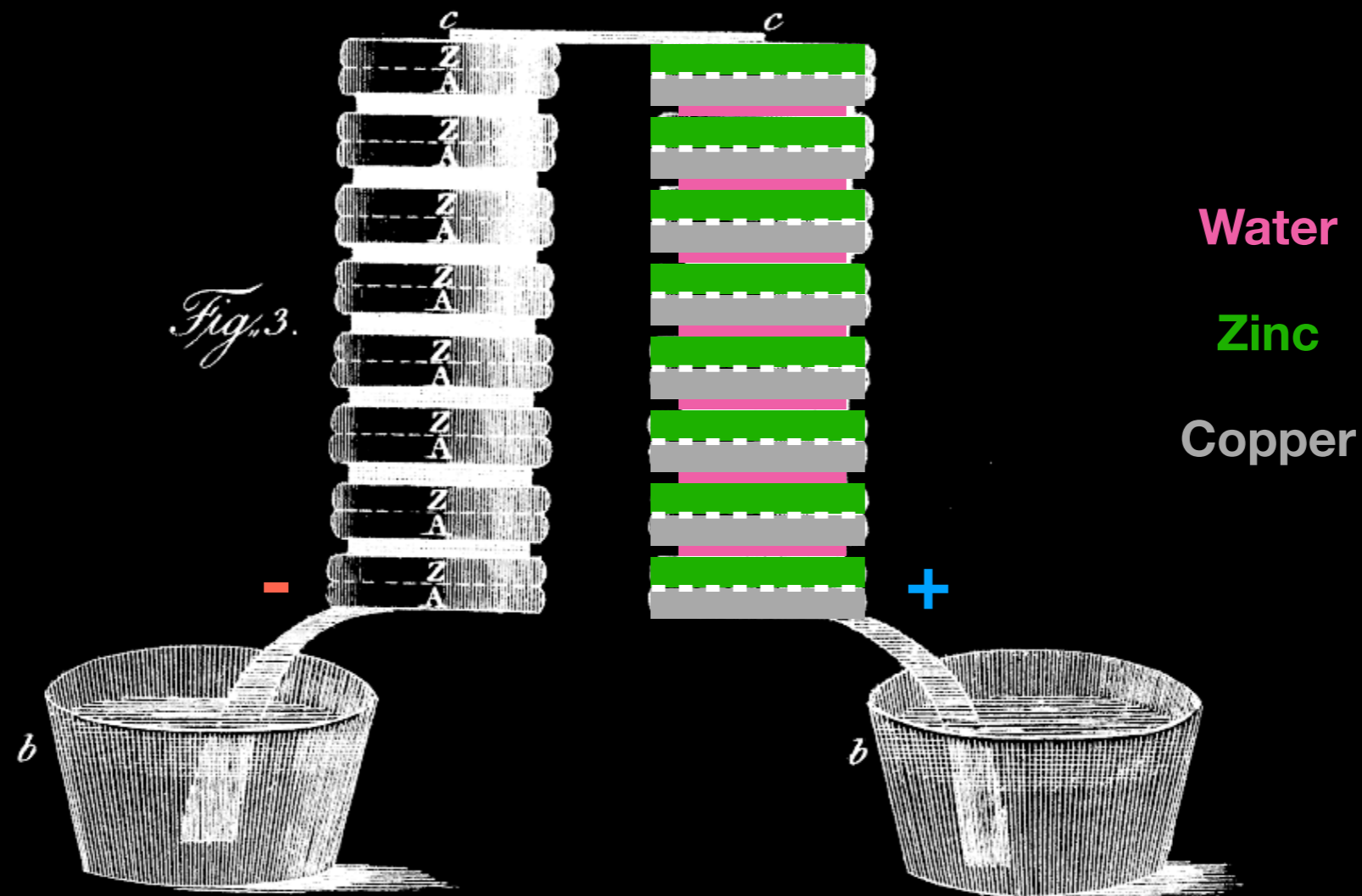
"This is all that is necessary for constituting my new instrument, which, as I have said, imitates the effects of the Leyden flasks."



Volta's "artificial electric organ"

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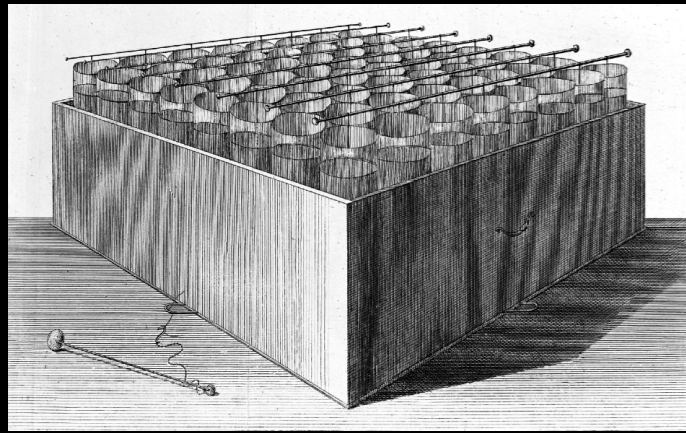
"To this apparatus, much more similar to the natural electric organ of the electric eel than to the Leyden flask and electric batteries, I would wish to give the name of the artificial electric organ."



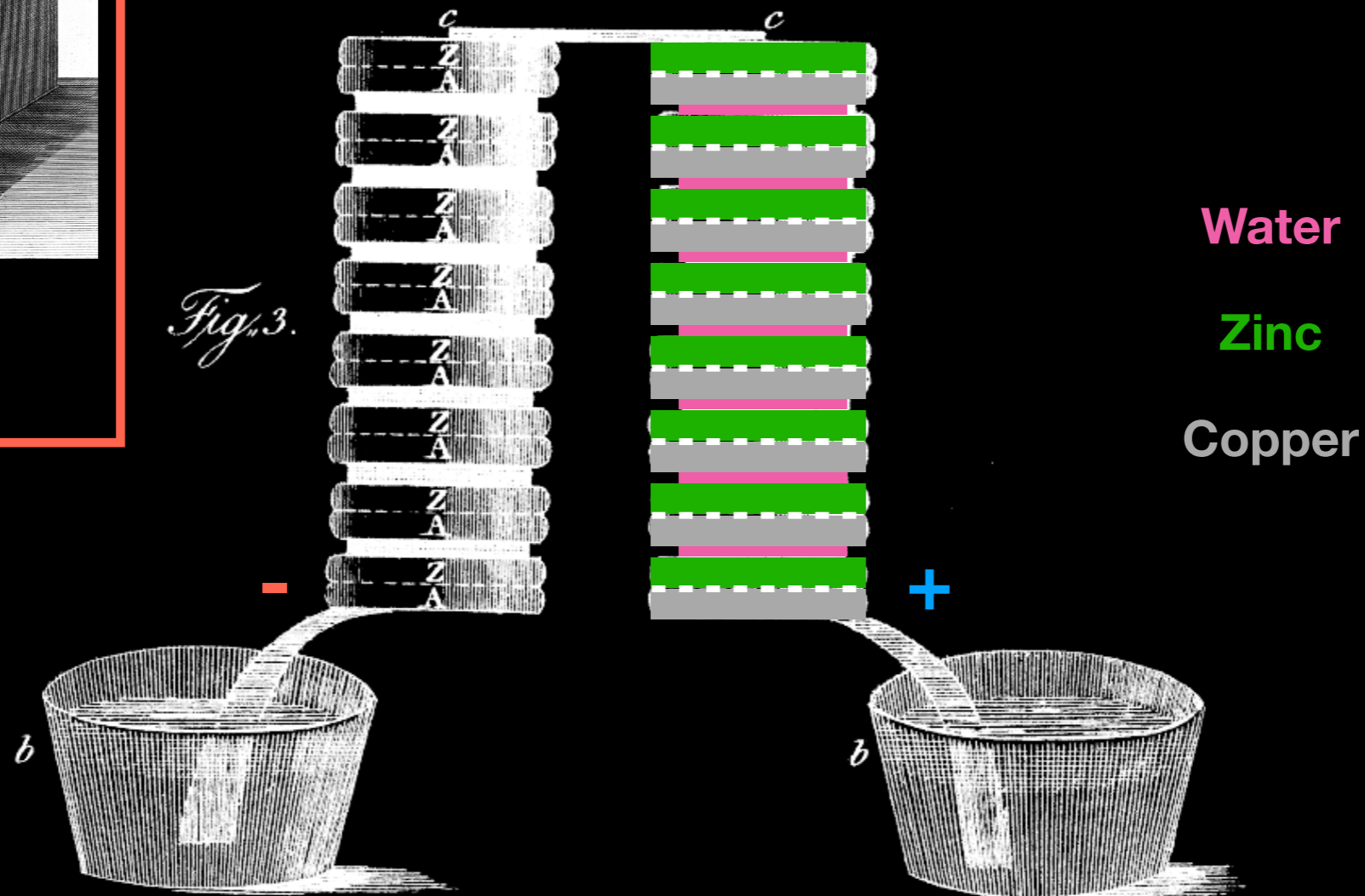
Volta's "artificial electric organ"

In a letter to the Royal Society, March 1800:

"To this apparatus, much more similar to the natural electric organ of the electric eel than to the Leyden flask and electric batteries, I would wish to give the name of the artificial electric organ."



"Battery" of Leyden Jars



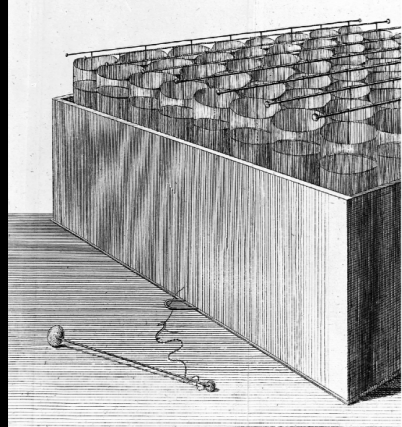
Volta's "artificial electric organ"

In a letter to the Royal Society, March 1800:

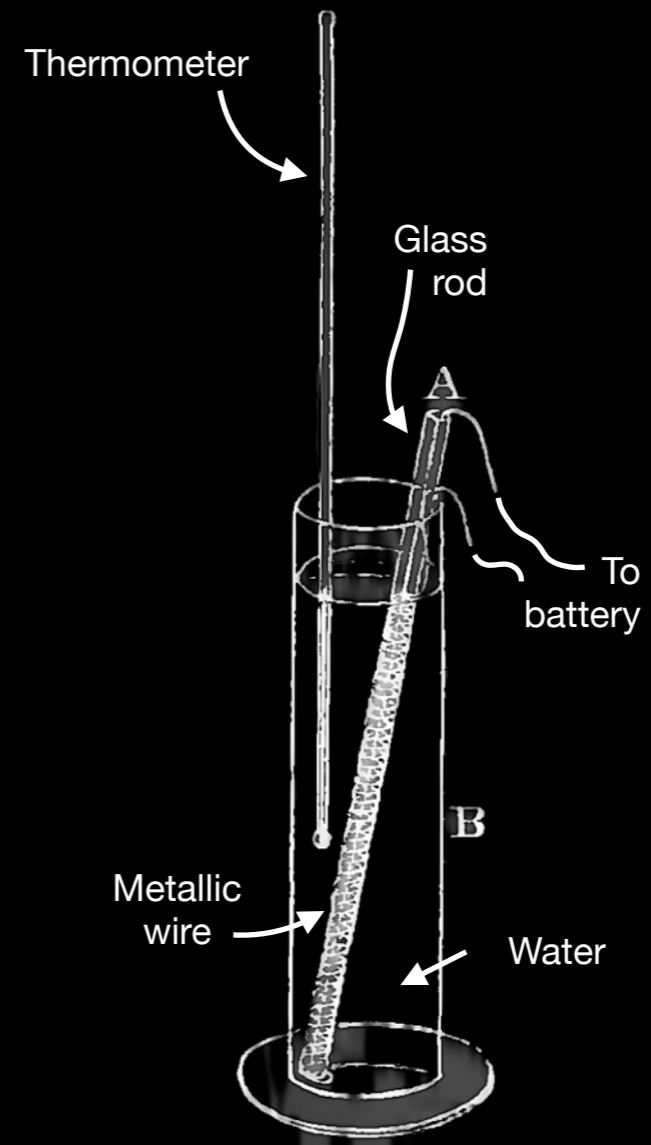
"To this
than to

James Joule (ca. 1840):

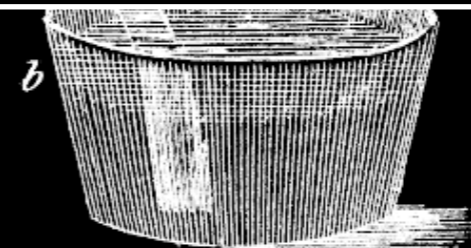
*[...] when a current of voltaic
electricity is propagated along a
metallic conductor [...]*



"Battery
Leyden



electric eel
e of the



Volta's "artificial electric organ"

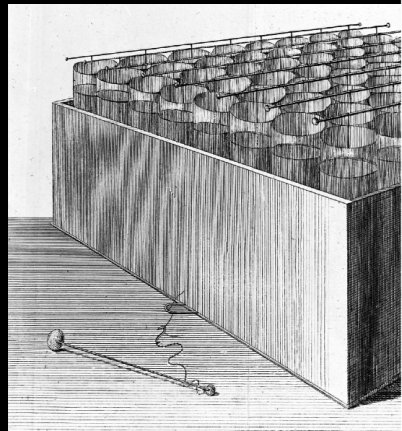
In a letter to the Royal Society, March 1800:

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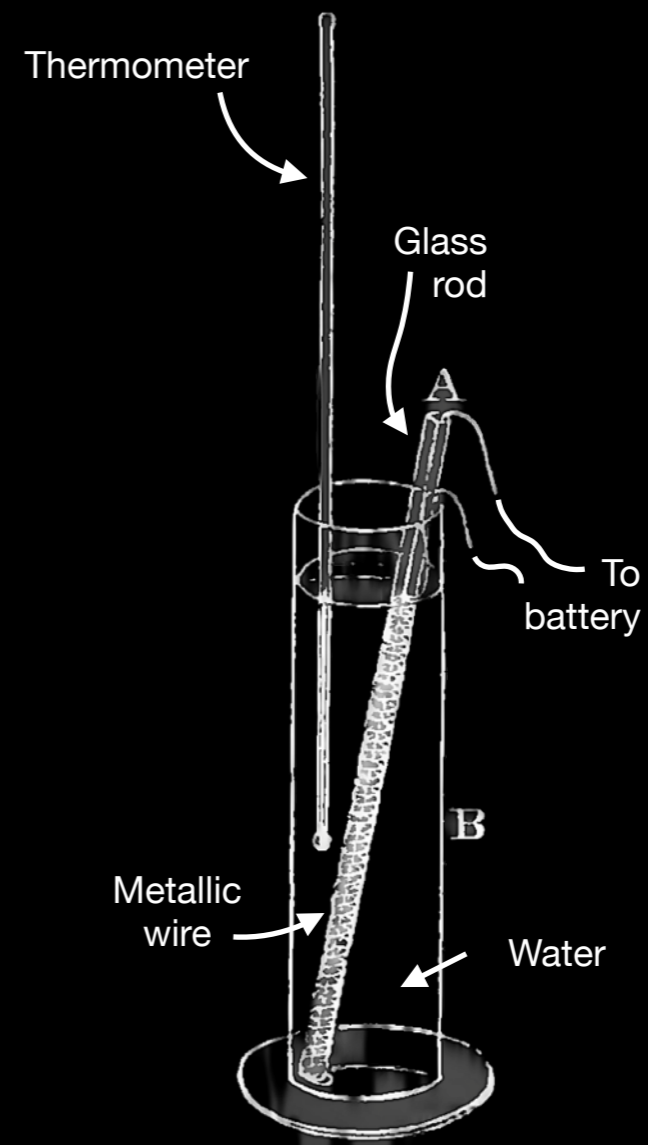
James Joule (ca. 1840):

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

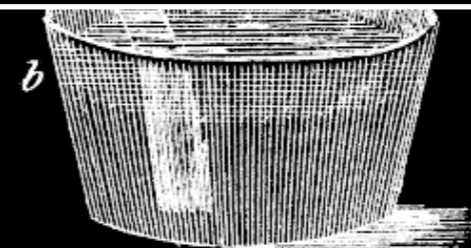
The first "steady-state" source of electricity!



"Battery
Leyden



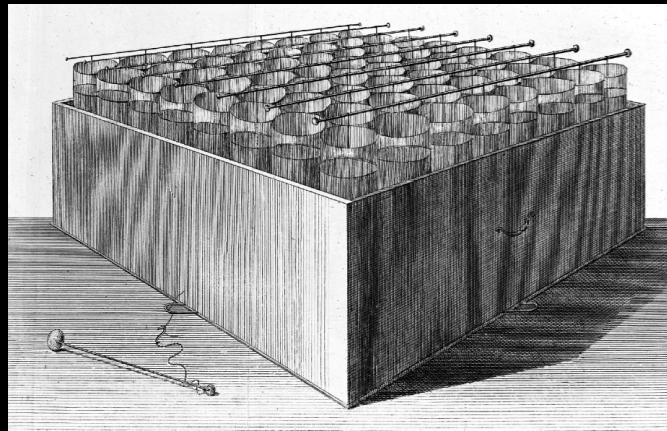
electric eel
e of the



Volta's "artificial electric organ"

In a letter to the Royal Society, March 1800:

"To this apparatus, much more similar to the natural electric organ of the electric eel than to the Leyden Jar, I have given the name of the



"Battery" of
Leyden Jars

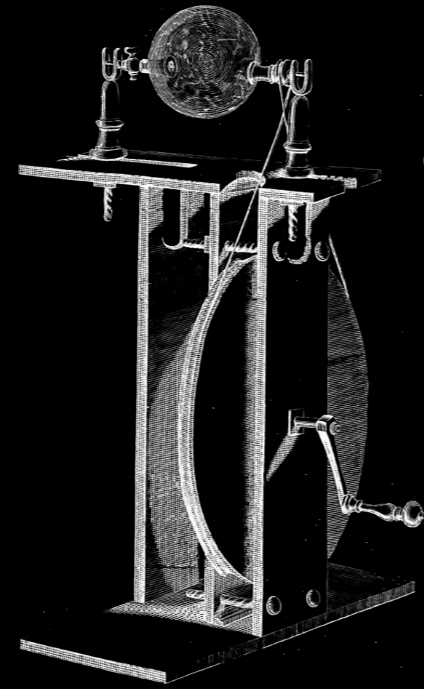


Still a very convenient source of
electricity!



**The state of electricity
in 1800: utter confusion!**

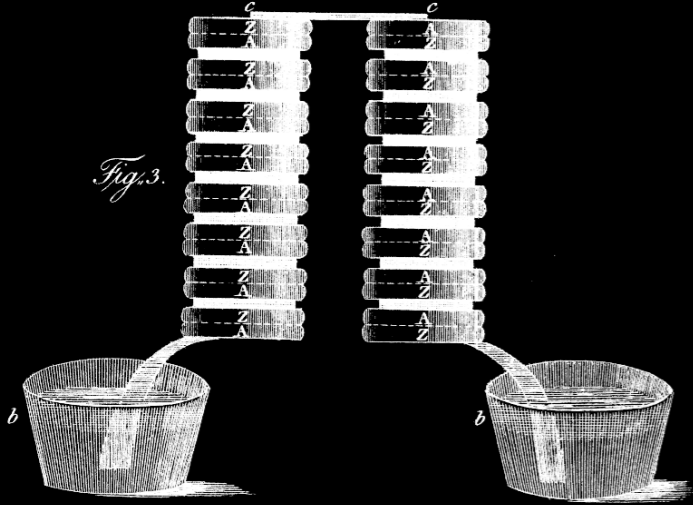
**The state of electricity
in 1800: utter confusion!**



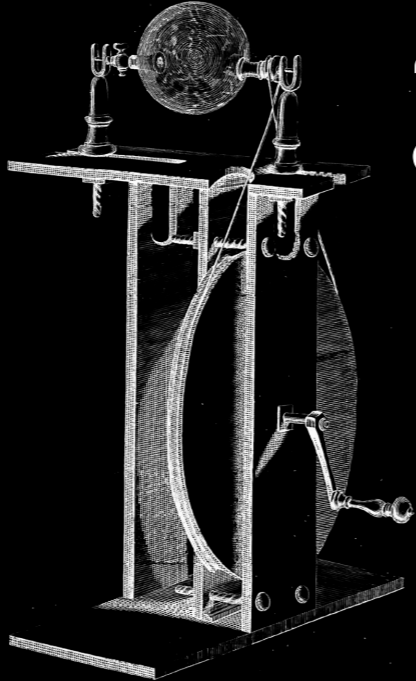
“Ordinary”
electricity

**The state of electricity
in 1800: utter confusion!**

Voltaic electricity

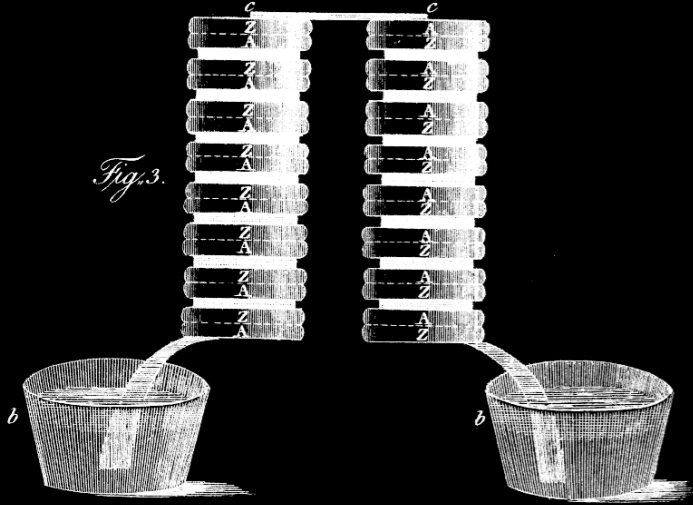


“Ordinary”
electricity

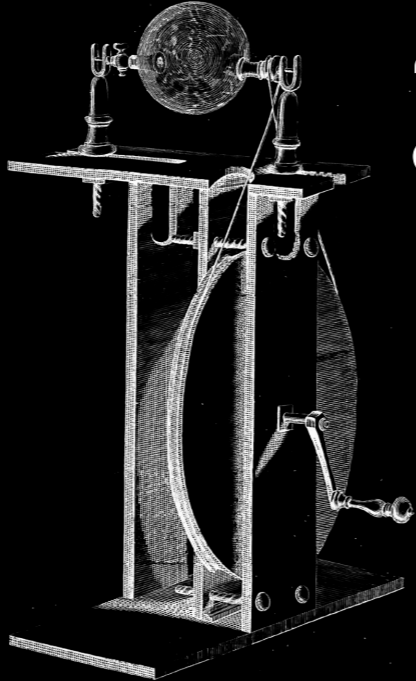


The state of electricity
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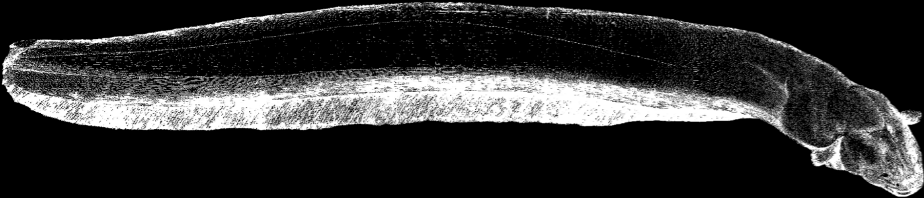
Voltaic electricity



“Ordinary”
electricity

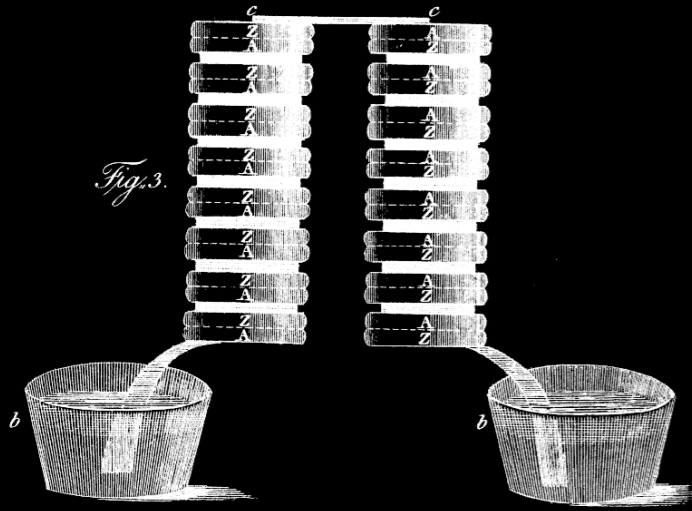


Animal electricity

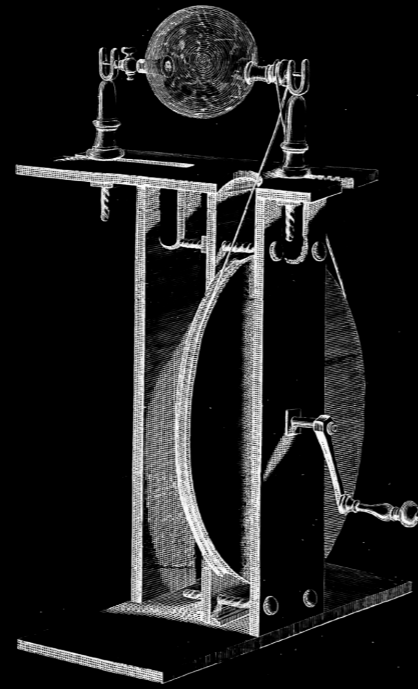


The state of electricity
in 1800: utter confusion!

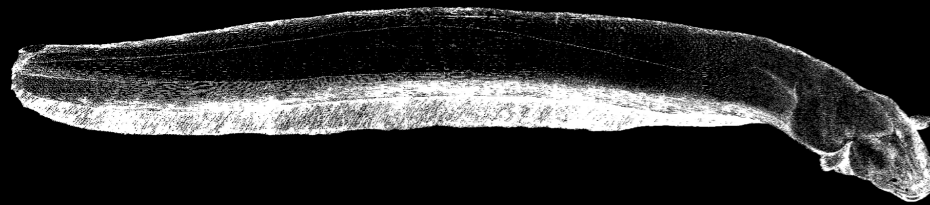
Voltaic electricity



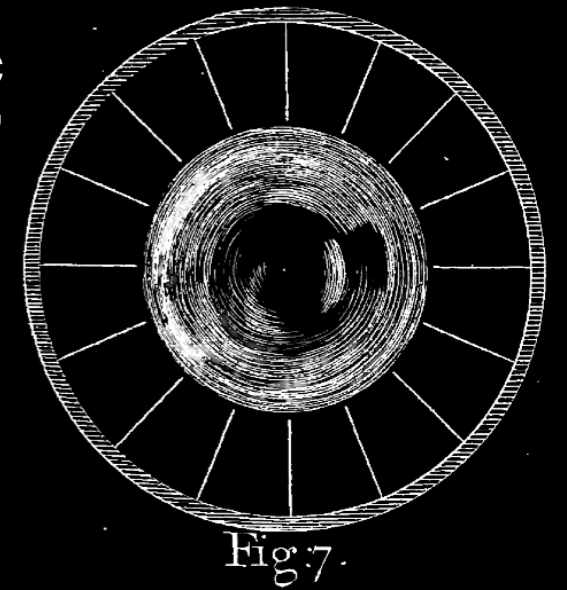
“Ordinary”
electricity



Animal electricity

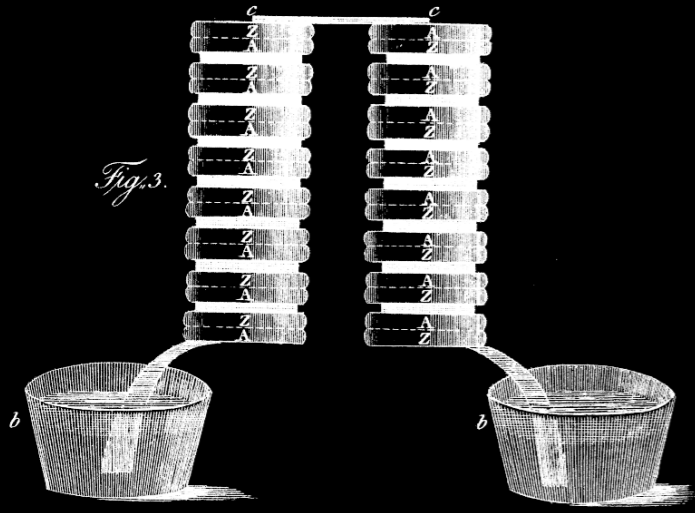


“Electric
spiderwebs”

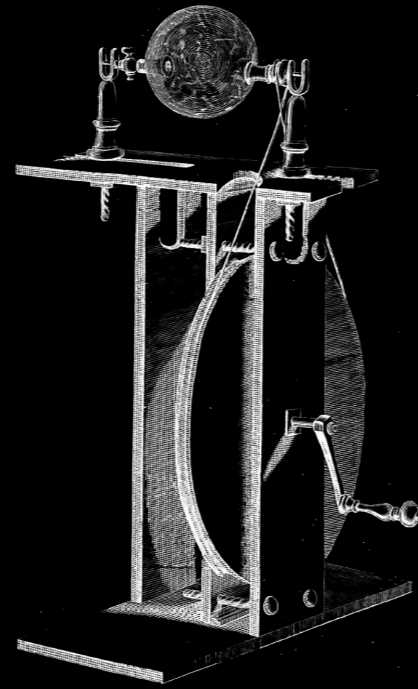


The state of electricity in 1800: utter confusion!

Voltaic electricity



“Ordinary” electricity

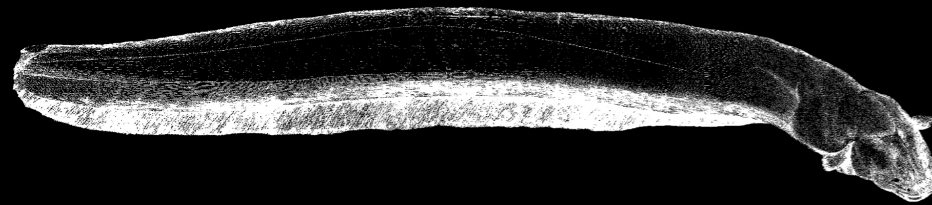


“Vitreous”

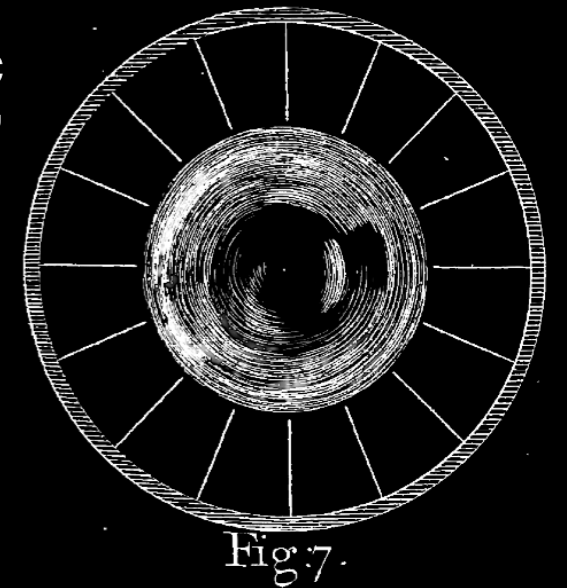
“Resinous”

“Two kinds of electricks”

Animal electricity

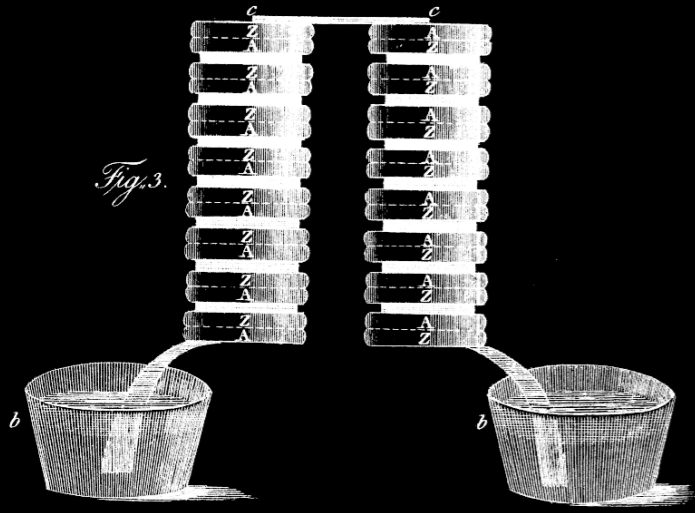


“Electric spiderwebs”

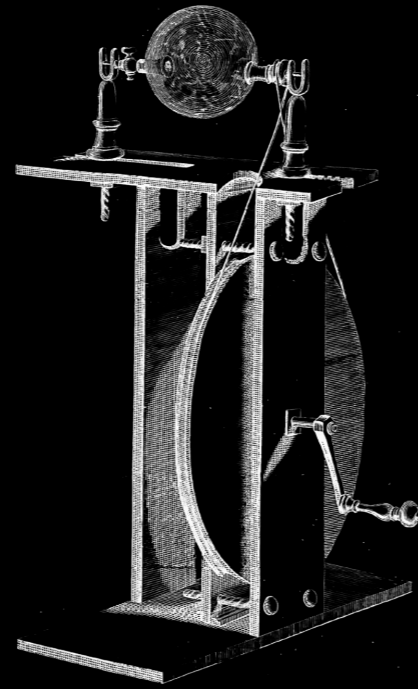


The state of electricity in 1800: utter confusion!

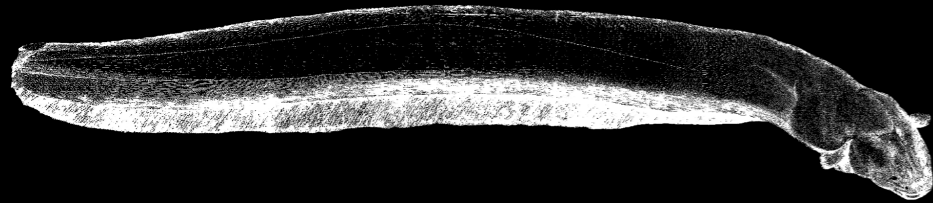
Voltaic electricity



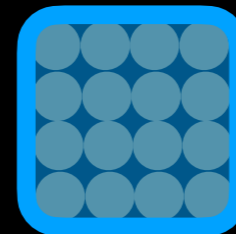
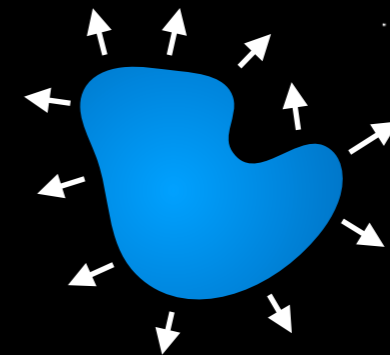
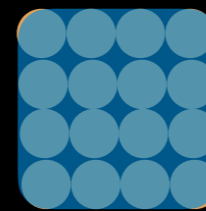
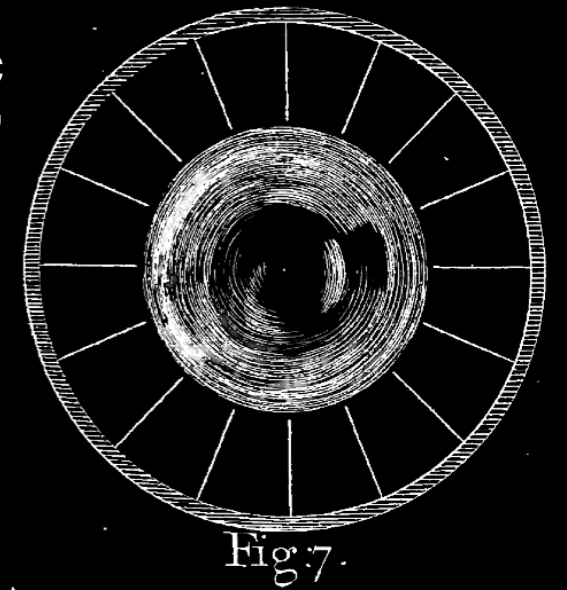
“Ordinary” electricity



Animal electricity



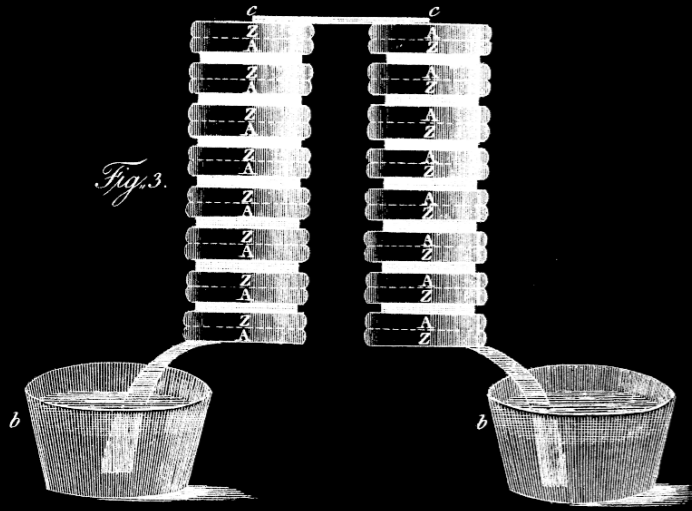
“Electric spiderwebs”



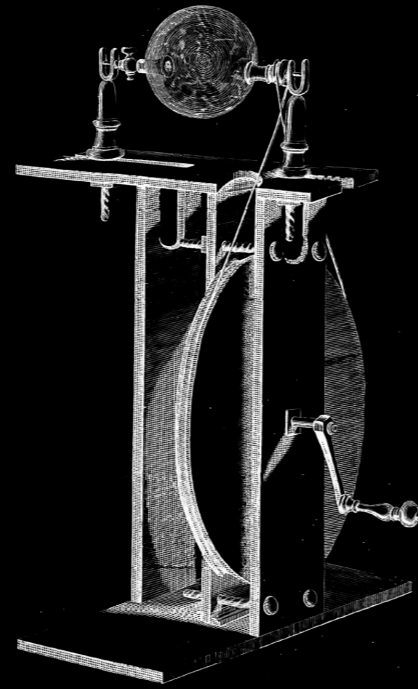
“Electrical atmospheres”

The state of electricity in 1800: utter confusion!

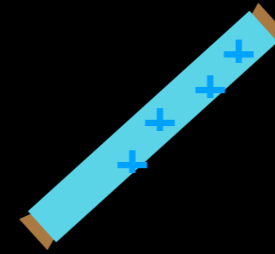
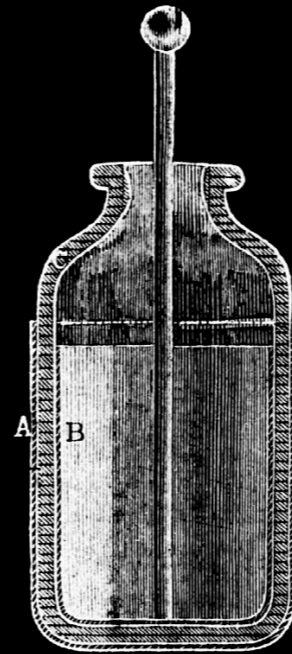
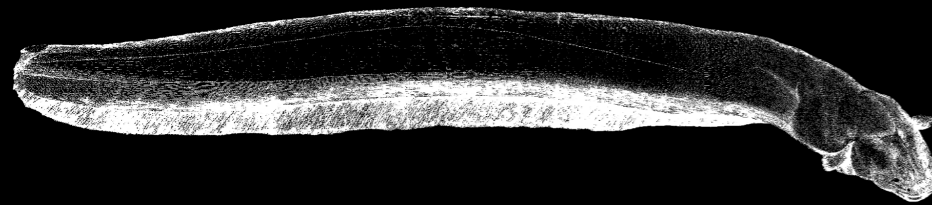
Voltaic electricity



“Ordinary” electricity



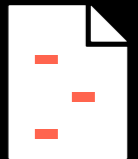
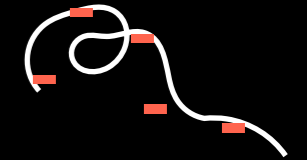
Animal electricity



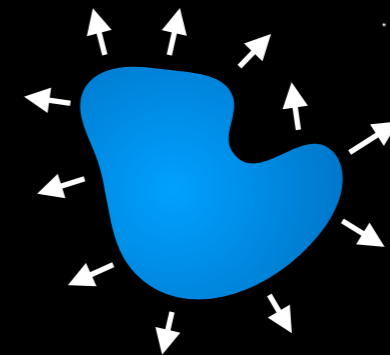
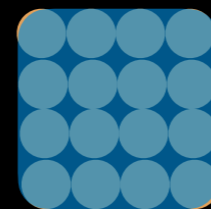
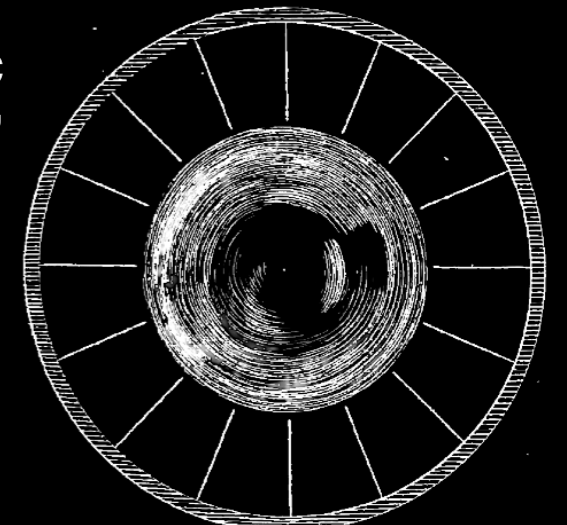
“Vitreous”

“Resinous”

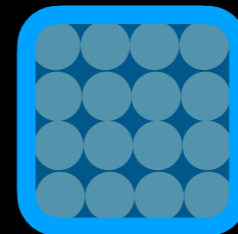
“Two kinds of electricks”



“Electric spiderwebs”

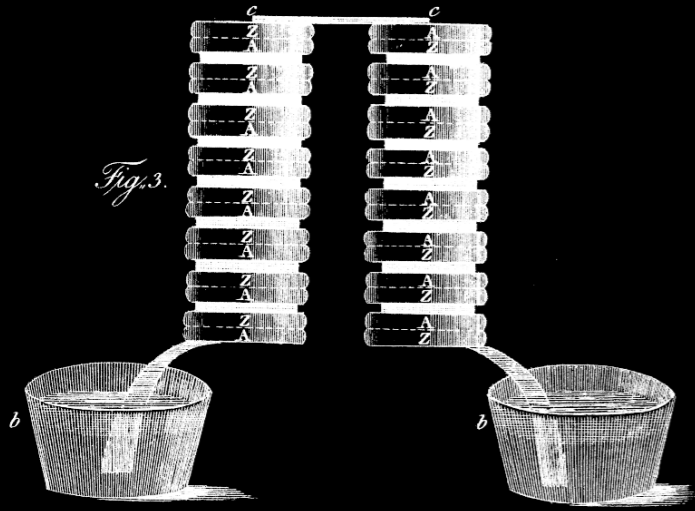


“Electrical atmospheres”

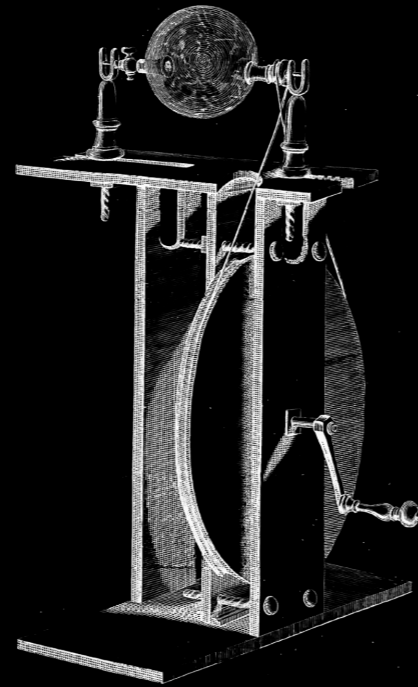


The state of electricity in 1800: utter confusion!

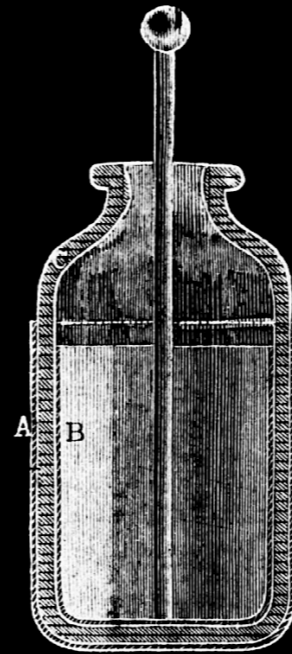
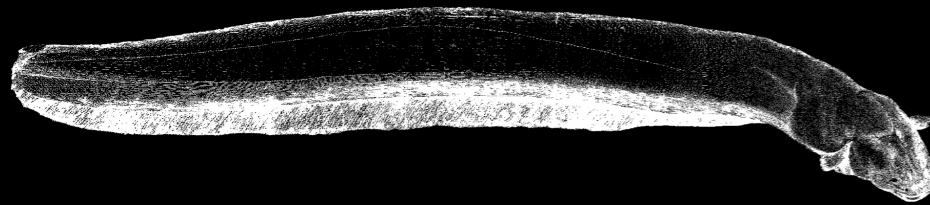
Voltaic electricity



“Ordinary” electricity



Animal electricity

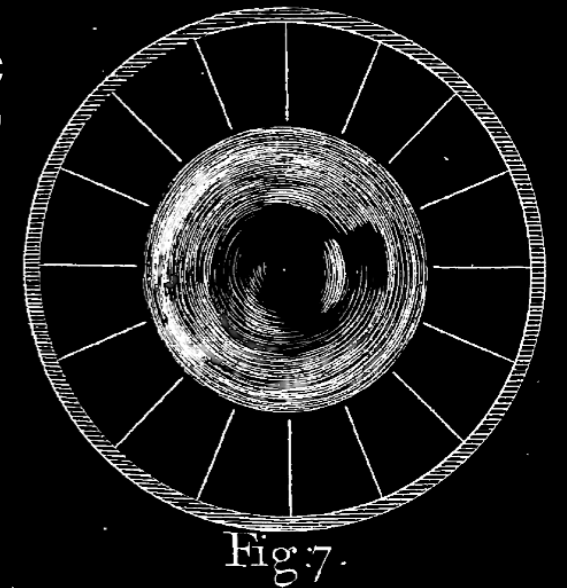


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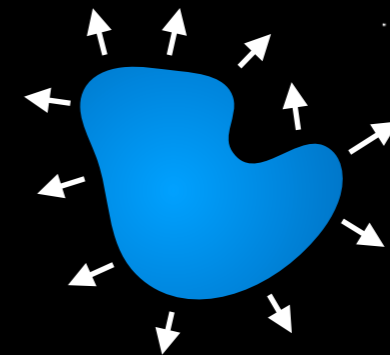
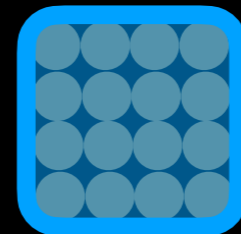
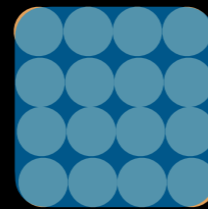
“Two kinds of electricks”

“Electric spiderwebs”



It will get worse before it gets better ...

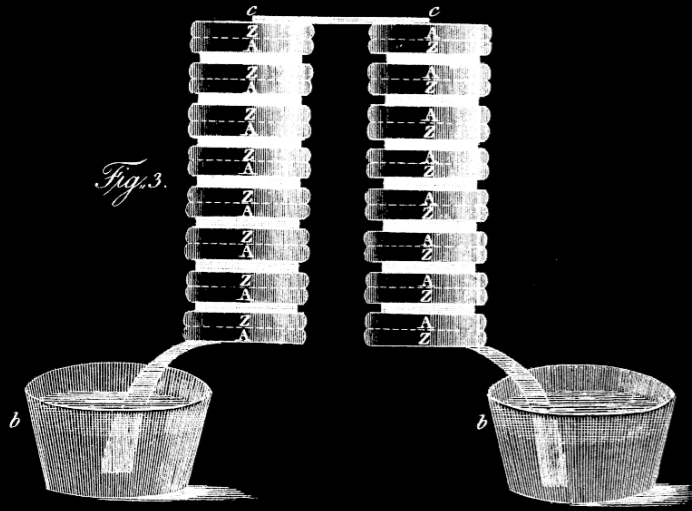
... next time!



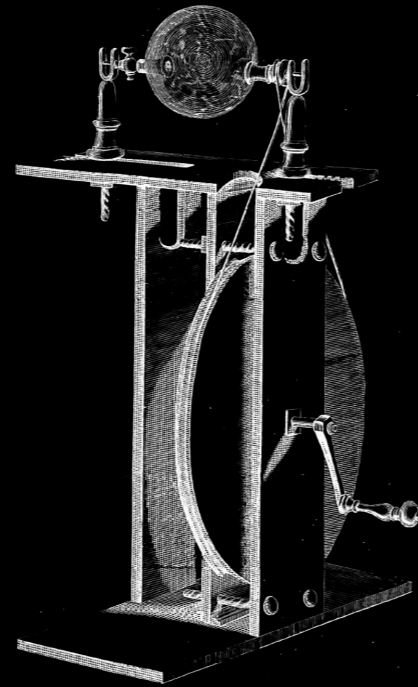
“Electrical atmospheres”

The state of electricity in 1800: utter confusion!

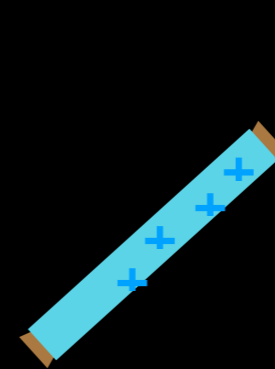
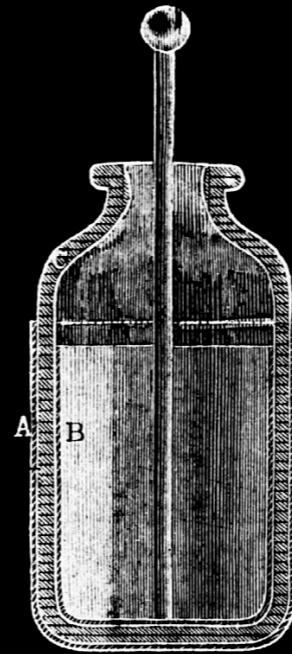
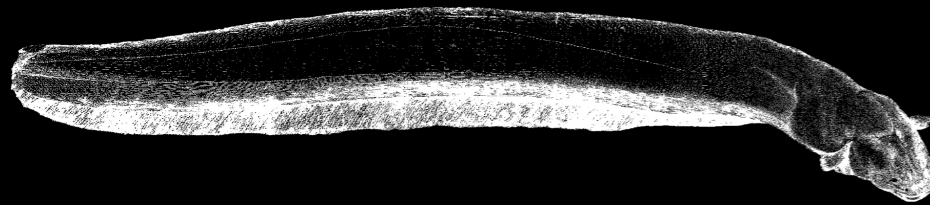
Voltaic electricity



“Ordinary” electricity



Animal electricity

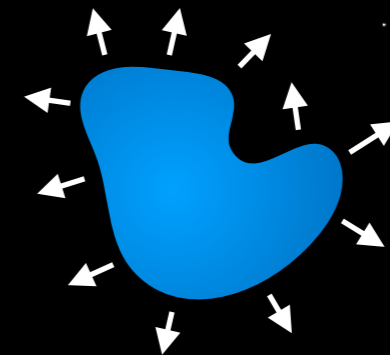
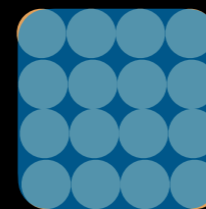
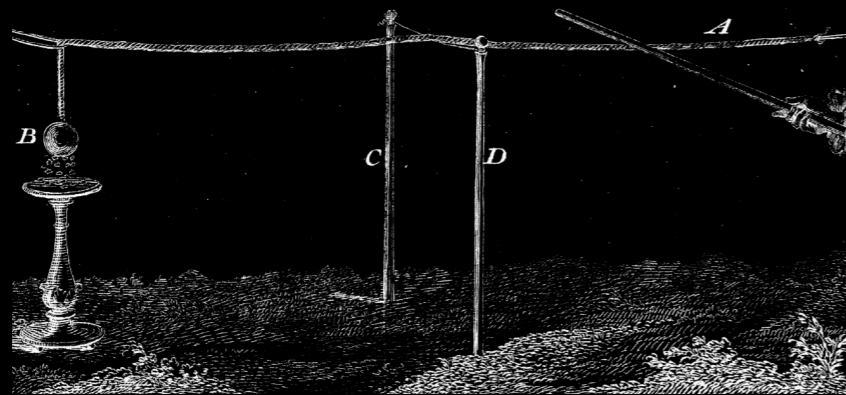
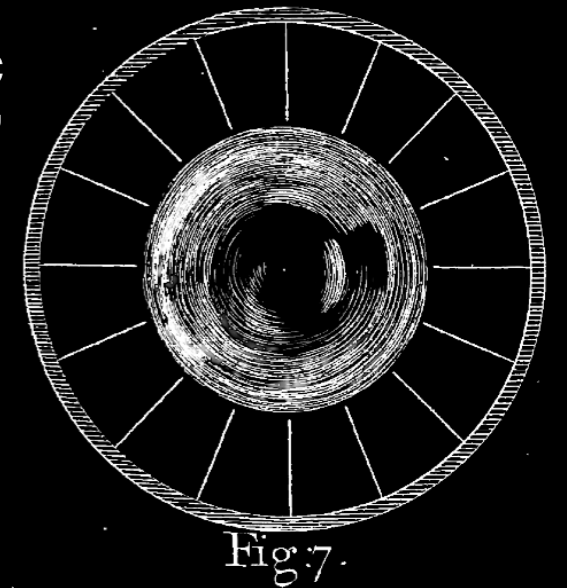


“Vitreous”

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**HOW FUNDAMENTAL SCIENCE
HAS CHANGED THE WORLD**

A STORY OF INVENTION AND DISCOVERY