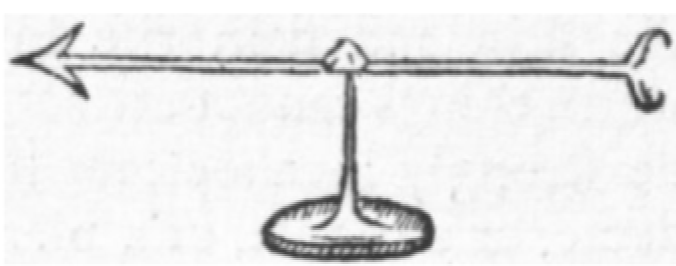
Gilbert's Discovery of 'Electricks'
Research Highlights

Summary
In 1600, William Gilbert published *De magnete*, a treatise on magnetism that presented a new magnetic cosmology meant to displace Aristotle's, and that includes the central claim that the Earth is a giant magnet. Gilbert devotes one of the more than one hundred chapters of *De magnete* to the subject of "electricks," i.e., "things which attract in the same manner as amber." Gilbert's treatment of electricks, by far the most sophisticated account of amber-like attraction to date, properly constituted the discovery of static electric attraction and marked the beginning of the serious study of electricity.

The case study, [William Gilbert and the Discovery of 'Electricks,'] charts the history of the discovery of static electric attraction through multiple eras, from ancient Greece and Rome through the Middle Ages and the Renaissance to Gilbert. It covers the ancients' true and false claims about amber and lodestone; the independent development of magnetic study in the Middle Ages; the new true and false claims about the attractive powers of stones made by commentators in the Renaissance; and the development of the nascent field of magnetism by researchers, mariners, and compass-makers, up to and including Gilbert. It then delves into Gilbert himself, examining his dispositions, evidential landscape, investigation of static electric attraction, results, and presentation of those results to the world.

This case is complex, partially because the story of Gilbert is not widely known and partially because what led Gilbert to electricks—namely, his attempt to develop a cosmological theory that reconciled magnetic observations with Copernican astronomy and to displace Aristotle—was complex. Despite its complexity, the study is nevertheless not a complete history of the early study of electricity; we have focused only on the parts we believe informed or led to Gilbert making his discovery.



Gilbert's diagram of the versorium.[1]

[1] William Gilbert, *On the Magnet*, trans. Silvanus P. Thompson (Urbana: Project Gutenberg, 2010), 49. [Link]

Background

Technical Background

- In the time before William Gilbert, people encountered static electric attraction when they found that amber and a number of other gems, when rubbed, attracted light objects such as straw, leaves, and chaff.

- Isolating static electric attraction involves (1) identifying that there is a type of object that exhibits an attractive power when rubbed, (2) distinguishing the relevant attractive power from magnetic attraction, which is exhibited by lodestones and magnetized iron, and (3) distinguishing the relevant type of object from other nearby categories with which it might be confused, which in this case means recognizing that the category of static electric attractor includes more than amber and overlaps imperfectly with the category of gems. With respect to the latter point, static electric attractors include some but not all gems (e.g., amber, diamond, and jet, but not emerald or pearl), and some but not all non-gems (e.g., sulfur and glass, but not gold, silver, ivory, or cedar).

- Static electric attraction can be subtle and finicky, making it difficult to identify the pattern. The effects are sometimes very slight, and can be obfuscated by gravity. The effects are also irregular: while static electric attraction is usually produced by rubbing the relevant materials, in some cases the materials behave as conductors rather than insulators and the effect is not produced. Static electric attraction is also affected by the weather, including temperature and humidity, and can vary based on differences in what seem to be the same materials (e.g., glass with different compositions, variations in jet).

References
— For more on what is involved in isolating static electric attraction, or on what constitutes its discovery, see 5–7.
— For a more in-depth discussion of the technical details of static electric attraction, see appendix C, esp. 89–93.

Research Highlights

This section summarizes the main conclusions from our study of Gilbert's discovery of static electric attraction. For further reading, references to the case study and some external sources are provided. References that include only page numbers correspond to the case study. For external references, full bibliographical information is given in the case study bibliography.

1) Writers in ancient Greece and Rome remarked on the attractive powers of various stones, especially amber and lodestone. In addition to their true observations, they also made several false claims, including false observational claims.

Explanation

Several ancient authors, including Thales, Plato, Pliny the Elder, and Plutarch, comment in their writings on the attractive powers of various stones, including amber, lodestone, ruby, garnet, and others. Between them, they note correctly that amber, when rubbed, attracts many light objects, that lodestone attracts iron and causes iron to attract further iron, and that some other stones are similar to amber in attractive power. But they also make false claims, including some that could have been falsified by observation, including that amber does not attract basil or things dipped in oil, or that garlic cancels the power of the lodestone. Some authors made more fantastical claims as well.

References

— On correct observations made by the ancients, see 12–14.

— On the ancients' mistaken claims and more fantastical bits of misinformation, see 15–17.

2) Writers during the Renaissance continued the pattern of commentary on stones with attractive powers, treating the stones at greater length, making new and important observations, correcting some past errors, and introducing novel errors of their own.

Explanation

A number of Renaissance writers returned to the topic of the attractive powers of various stones. Their treatments were now longer, and they added several important true claims about amber attraction. Georg Agricola, a mineralogist and physician, for instance, correctly observes that amber attracts all light objects, while Girolamo Fracastoro, another physician, notes that diamond attracts like amber. Some Renaissance writers correct ancient myths, such as amber failing to attract basil or garlic preventing lodestone attraction. The best of these writers on the topic of attractive stones was Girolamo Cardano, who explicitly contrasts amber and lodestone attraction and notes that interposed materials block amber attraction but not lodestone attraction. Nevertheless, despite the improvement in quality, Renaissance writers continue to introduce new false claims, such as that gray amber rubbed with iron can attract leaves from two feet away (Agricola), that lodestone attracts silver (Fracastoro), and that all gems attract (Cardano).

References

— On observations made by Renaissance authors and how they did and did not overcome the errors of the ancients, see 27–32.

— For a discussion of Girolamo Cardano, who came the closest to isolating static electric attraction prior to Gilbert, see 7, 30–32.

3) Ancient and Renaissance thinkers employed a variety of theories of attraction to explain amber and lodestone attraction. These theories, however, did not suggest that there was an important difference between the two.

Explanation

Ancient thinkers developed a range of theories to explain attraction, especially lodestone attraction. Epicurus attempts to explain lodestone attraction mechanically, proposing that lodestone and iron exude atoms that rebound off each other, become entangled, and pull each other together. Lucretius suggests that the lodestone spews seeds that create a vacuum, thereby drawing the iron in. Plato proposes that amber and lodestone attraction will both be explained by the dynamics of motion in a completely filled space. A number of thinkers in the Middle Ages and Renaissance employ the "Doctrine of Similitudes," which states that "like attracts like." None of these theories distinguish amber from lodestone, and thus were likely at best unhelpful.

References

— For a discussion of ancient theories of lodestone and amber attraction, including the theories of Galen and Thales, see 18–19.

— For a discussion of the Doctrine of Similitudes, see 36–37.

4) While there is little evidence of devices for detecting static electric attraction prior to Gilbert, the compass, as well as some descriptions of related devices, might have suggested to an enterprising thinker the possibility of creating an instrument for detecting amber-like attraction.

Explanation

The compass, which can be used both for navigation and to detect magnetic attraction from nearby lodestones, reached widespread use in the eleventh and twelfth centuries, and was well known. Some writers also mention instruments for detecting attraction, such as Fracastoro, who describes a "perpendiculo," or Cardano, who describes "magnetizing" a silver rod to enable it to detect large quantities of silver. Some scholars have proposed that Fracastoro's perpendiculo was an instrument for detecting static electric attraction, but the passage is ambiguous and perhaps best read as describing a variation on a compass. While there may not have been instruments before Gilbert that were used to detect static electric attraction, the existence of the compass and the mentions of devices by noted writers, even if ambiguous or otherwise dubious, might have suggested to some the idea of an instrument that would detect amber-like attraction.

References

— On the possibility of instruments that might have been used to detect static electric attraction, see 33–36.

— For a discussion of Fracastoro's "perpendiculo," see 33–35. For interpretations in which Fracastoro's perpendiculo was an instrument for detecting static electric attraction, see Assis, *Foundations of Electricity*, 34; Saslow, *Magnetism, Electricity, and Light*, 68; and Heilbron, *Electricity in the 17th and 18th Centuries*, 175.

5) By Gilbert's time, a new field of magnetic research had appeared that identified many distinguishing factors about lodestones and magnetic attraction. This contributed to the isolation of static electric attraction by making it easier to distinguish it from magnetic attraction.

Explanation
In 1269 CE, Peter Peregrinus wrote a letter containing the first systematic study of magnetism, the *Epistola de Magnete.* In it, he gives instructions for creating a spherical lodestone for use in study, makes observations about the way lodestones have and interact with poles, gives clear instructions for simple experiments to run to reproduce his observations, and states a theory of lodestone attraction. The *Epistola* was not widely circulated until 1558 CE, after which point other researchers, including William Gilbert, replicated Peregrinus's experiments and worked to extend his research program. With magnetic attraction now being studied more closely and becoming better understood, it became easier to distinguish from static electric attraction.

References
— For an extended treatment of Peregrinus's contributions to magnetic study, see 20–26.
— For a description of efforts to extend Peregrinus's research program further prior to Gilbert, see 38–42.

6) Gilbert's primary research focus was not electricity, but instead the construction of a magnetic cosmology centered around the claim that the Earth is a giant magnet. This theory was intended to explain recent observations in the fields of magnetism and astronomy, and to displace Aristotle's cosmology, which prevailed at the time.

Explanation
Gilbert wrote two works, *De magnete* and *De mundo*. In *De magnete*, he describes many properties of magnets, details a large number of magnetic experiments, and presents a magnetic cosmology according to which the Earth itself is a giant magnet. Gilbert then uses the magnetic nature of the Earth to explain puzzling magnetic phenomena such as magnetic dip (i.e., that compass needles sometimes tilt downward) and magnetic variation (i.e., that compass needles do not uniformly point to the poles of the heavens). He also proposes a rotational power of magnets to explain Copernicus's proposed rotation of the Earth on its axis, and does so in a way that is consistent with, but silent on, the question of Copernicus's heliocentrism. Gilbert intended his

magnetic cosmology, centered on magnetic Earth, to replace Aristotle's cosmology of Fire, Water, Earth, and Air. In *De mundo*, Gilbert attempts to explain many terrestrial phenomena previously explained by Aristotle by referring to the magnetic Earth and its various corruptions.

— For more on *De magnete* and *De mundo*, see 46–51.
— For a description of Gilbert's views on magnetic behaviors, see appendix B, 84–85.
— On Gilbert's magnetic theory of the Earth, see 54–55, 57.
— Regarding magnetic dip, for its discovery, see 39; for it as a phenomenon to be explained, see 53–54; and for Gilbert's explanation, see 55–56.
— Regarding magnetic variation, for evidence of it, see 42–43; for it as a phenomenon to be explained, see 53–54; and for Gilbert's explanation, see 56–57.
— For background on Aristotle's cosmology, see 44–45.
— For a description of Copernicus's challenge to Aristotle's cosmology, see 44–46.
— For the rotation of the Earth as a phenomenon to be explained, see 54; for Gilbert's attempted explanation, see 57.

7) While Gilbert does not say what led him to investigate attraction by amber and other gems, it is natural to see his investigation as arising directly from his study of magnetism and his attempt to construct a magnetic cosmological theory.

Explanation
While scholars have focused on Gilbert's penchant for experiment, especially in connection with the beginning of the Scientific Revolution, it is hard to assign this proclivity for experiment as the precipitating cause of Gilbert's investigation of amber-like attraction. Instead, it seems much more plausible to explain his investigation as arising naturally from his attempt to develop his magnetic cosmology. This might have happened in a number of ways; for instance, Gilbert might have thought a systematic treatise with lodestone attraction as its centerpiece would naturally need to carefully distinguish lodestone attraction from other cases of attraction—especially those with which lodestone attraction was frequently confused, such as amber attraction.

— For discussions of Gilbert's use of experiment, see Zilsel, "The Origins of William Gilbert's Scientific Method" and Henry, "Animism and Empiricism: Copernican Physics and the Origins of William Gilbert's Experimental Method."
— On Gilbert's proclivity for experiment, see 49–50.
— For a discussion of explanations for Gilbert's investigation that derive from his cosmological magnetic theory, see 58–59. For an author who concurs while offering differing particulars, see Benjamin, *History of Electricity*, 294–297.
— For a brief discussion of other possible explanations, see 58.

8) Gilbert's study of the attractive powers of materials involved both a thorough review of previous research and an extensive experimental investigation.

Explanation
In his research on amber-like attraction, Gilbert covers many writers, including Lucretius, Pliny, Plutarch, Solinus, Galen, Agricola, Cardano, Fracastoro, da Orto, Scaliger, Porta, and Norman. He confirms some of their claims and dispatches the rest with experiments, simple causal arguments, and the occasional helping of disdain. Gilbert also conducted his own extensive experiments, learning to control conditions and testing more materials under more conditions than any of the previous authors. For instance, he tested materials other than stones, such as bones, woods, and herbs, tested things that crumbled easily, and showed that rubbed amber attracts water but not flame.

— On Gilbert's penchant for responding to his predecessors, see 47–49.
— For a description of how previous research likely aided Gilbert's investigation, see 60.
— For a description of Gilbert's electrical experiments, see 60–61.

9) Gilbert developed an instrument for detecting subtle electric effects, the non-magnetic versorium. It is unclear whether he used the versorium in his research or whether he developed it afterward to help him convey his results to others.

Explanation
In *De magnete*, Gilbert describes and includes an illustration of a pivoted metal needle that can be used to detect subtle electric effects. This was likely the first electroscope; Gilbert called it the "non-magnetic versorium," or simply the "versorium." While it is perhaps natural to assume that he used the versorium in his research, there is no clear evidence of this, and it remains quite possible that he made his electrical discoveries first and then developed the versorium to help convey those discoveries to others.

— For a description and Gilbert's illustration of the versorium, see 64–65.

10) Through his efforts, Gilbert identified the category of "things that attract in the same manner as amber," which he called *electricks*. He identified a long list of electricks and non-electricks, clearly distinguished static electric attraction from magnetic attraction, and distinguished the category of electricks from other nearby categories.

Explanation
Gilbert identifies many electricks, including amber, jet, diamond, sapphire, carbuncle, iris stone, opal, amethyst, glass, belemnites, sulfur, mastic, lac sealing wax, hard resin, orpiment, rock salt,

mica, rock alum, and others. He also identifies many non-electricks, including emerald, agate, carnelian, pearls, coral, flint, bone, ivory, ebony, cedar, silver, gold, iron, lodestone, flesh, herbs, and "very many other things." He identifies several features of static electric attraction, noting that electricks attract all things, attraction by electricks is blocked by interposed objects, is comparatively weak, is affected by humidity, and so on. These features, along with the list of electricks, adequately distinguish electricks from magneticks, and electricks from other nearby categories such as gems. Thus Gilbert, through his efforts, identifies and isolates static electric attraction.

— For the results of Gilbert's investigation of electricks, see 61–63 and appendix A, 83–84.
— What constitutes the discovery or isolation of static electric attraction is covered in the "Technical Background" on p. 2 of this document.

11) Gilbert presented his results in a chapter of his work *De magnete*, published in 1600. His exposition departed from that of his predecessors in both content and form, and made it easy for others to adopt and extend his research program.

Explanation
While Gilbert devoted only one of the 115 chapters of *De magnete* to electricks, his clear and thorough treatment of the matter was a distinct departure from those of his predecessors. He devotes an entire chapter to the topic, whereas previous writers wrote only a few paragraphs or a few sentences. He gives the object of study a new and evocative name, *electricks*, and presents an authoritative history of the subject, thereby elevating it in status and importance. Gilbert includes a large number of claims, many of them new, and describes experiments that can be run to confirm his results. He also provides a description and illustration of his experimental tool, the versorium, that other researchers can use as they replicate his experiments or conduct their own.

References
— On Gilbert's presentation of his electrical results, see 65–66.

12) Gilbert's work was later picked up by others who used the versorium, added to (and corrected) his list of electricks and non-electricks, challenged his effluvial theory, developed new instruments, and otherwise continued and extended his research. Serious electrical study had begun.

Explanation
By the mid to late 1600s, Gilbert's category of electricks was widely recognized and his research was being extended. Robert Boyle, first publishing in 1660, for instance, used the versorium, added new electricks to Gilbert's list (including emerald, contradicting Gilbert), and disputed

Gilbert’s effluvial theory. Others followed suit, leading to the discovery of conductors and insulators, and eventually to the unification of electricity, magnetism, and light by Maxwell.

References
— For a brief description of electrical study after Gilbert, see 66–67.