The Development and Spread of Franklinian Theory: Research Highlights

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Summary

Benjamin Franklin's theory of electricity is often seen as the first to address the phenomenon in a systematic and experimentally productive manner. The account became popular soon after the publication of his *Experiments and Observations on Electricity* in 1751 and served as a base for subsequent developments by Aepinus, Cavendish, and an array of other electricians across Europe. By the 1770s, "Franklinism" had become the most widely accepted view of electricity to date. Indeed, many of the theory's core terms and notions, including the use of the word "battery" and the critical distinction between positive and negative charge, are still with us today. "The Development and Spread of Franklinian Theory" documents the genesis of Franklin's ideas and outlines the various reasons for their adoption.

Traditionally, narratives of Franklin's impact have relied heavily on the conceptual novelty of his account. It has, for instance, been claimed that Franklin was the first to make substantial use of conservation principles and to present electricity as an elastic fluid subject to Newtonian attraction and repulsion. In reviewing the evidence, however, it becomes clear that the features most frequently cited as Franklinian novelties were, in fact, present in previous research, with the most striking example coming from the deeply similar but far less successful fluid theory of Prussian engineer Jacob von Waitz. While the success of Franklin's framework cannot be separated from the concepts it employs, the study argues, the fact of Waitz's parallel account suggests that the American's impact was not solely or primarily based on its conceptual novelty.

Ultimately, what set Franklin apart was (a) the practical bent in his exposition, which made it easier for other electricians to interpret and use, and (b) the growth of a liberal political culture eager for a promethean figure to use in broader disputes over humanity's place in nature. While Franklin's account was similar to earlier proposals in terms of fundamental assumptions, it differed markedly in presentation and the specific manner in which it was formulated. In contrast to earlier treatments, Franklin stated the theory quite directly and consistently anchored it to measurable phenomena, rendering it far easier to follow and apply. At the same time, Franklin's account was among the first to be formulated after the discovery of the Leyden jar, an early capacitor that allowed electricians to store and deploy large quantities of electrical power. As such, the theory confronted an electrical community that was unified in terms of interest (the mysterious jar more or less setting the agenda) and an experimental context with far more reliable and impressive phenomena, phenomena that Franklin's versatile theory was, to some

extent, built to explain. Finally, the American's accomplishments—most significantly, his creation of the lightning rod—played naturally into mid-to-late eighteenth-century progress narratives. In an era of increasing secularization and growing republican sentiments, the "freethinking" Franklin's feat of snatching fire from the gods proved an irresistible symbol, propelling his system and the rhetoric surrounding it to unprecedented heights.

Background: The Structure and Main Applications of Franklin's Theory

The core of Franklinian theory is a set of precise, partially quantified claims that characterize the behavior of electricity in terms of an underlying fluid. This fluid was said to be composed of exceptionally small particles, allowing it to pass through most other substances, and each particle was said to be both attracted to non-electric matter and repulsed by particles of the same type. The balancing of these attractive and repulsive forces, when paired with the non-electric materials' different shapes and levels of permeability, meant that different substances had different amounts of fluid natural to them. Under certain experimental conditions, however, this natural equilibrium could be disturbed, creating circumstances where some materials had less than their standard amount, which he labeled "negative" or "minus," and others had more than their share, which he classified as having "positive" or "plus" charge.

It was this altered state of affairs and the fluid's effort to return to its state of equilibrium that Franklin took to explain the range of documented electrical phenomena, such as the attraction and repulsion of light bodies (attributed to the attractive and repulsive properties of their constituent matter) and the apparent transfer of electric shocks from rubbed glass to insulated conductors (friction tearing the electric fluid from the glass and the attractive conductor drawing it in). Most significantly, Franklin's fluid account allowed him to make sense of the Leyden jar, an early form of capacitor that had been created a few years earlier. The prototypical device consisted of a glass jar filled with water and connected to an electric generator by way of a metal chain or wire fed through its mouth. To charge the jar, one simply connected the exterior surface to the ground while operating the generator, allowing positive charge to build up inside and depart outside (or, in terms of the underlying constituents, for negatively charged electrons to accumulate outside and depart from the inside). Once charged, the vessel delivered extremely powerful shocks to those who made contact with its base and wire. The discovery had a massive and near-instantaneous impact on the form of electrical experiment, allowing for more reliable and impressive displays as well as greater versatility (e.g., allowing large charges to be taken outdoors). At the time, however, relatively little space had been devoted to outlining the principles governing it, giving Franklin the opportunity to establish his own.

The theory also allowed him to design and execute a wealth of *novel* experiments. Franklin could anticipate the effect of chaining jars in series, for instance, and precisely modulate the strength of the attractive force exerted by the jar by adjusting its interior charge. Franklin's work also gave rise to a number of inventions, including an electrically propelled wheel and an entertaining “magic picture” that electrified those who attempted to remove an electrified metal crown from the image of George III. Famously, he also argued that pointed metal rods might be used to demonstrate the electrical nature of lightning and to prevent or re-direct strikes by siphoning fluid from the clouds (or, as he later came to believe, from the earth).

Research Highlights
The following represent the principal arguments and conclusions of the study. Relevant portions of the case study are provided below each highlight. External references have corresponding bibliography entries at the end of the case study itself.

1) Franklin’s theory was not radically new in its basic postulates.

Explanation
Franklin is sometimes credited with having laid down the principles and organized the central categories of electrostatics, outlining the relations between charge, capacity, conductance, and (implicitly) voltage. At the same time, he is frequently credited with having made a crucial step in the understanding of electric attraction and repulsion by attributing these to Newtonian distance forces acting on the underlying particles. A careful review of the prior literature suggests that most of these notions were present beforehand, however, and that at least one individual, Jakob von Waitz, anticipated nearly all of the functional elements of Franklin’s account. Both defended theories of electricity centered on a distinct fluid composed of particles attracted to non-electric substances and repelled by other particles of the same type; both modeled attraction and repulsion as distance forces; both distinguished between bodies housing their natural level of electric fluid and those pushed out of equilibrium, using the re-establishment of equilibrium to explain the experience of discharge and the strength of attraction and repulsion; and both explained conductance and non-conductance of different materials by reference to their pore structure. The central difference between them in terms of the basic principles was simply that Waitz thought the materials deemed overfilled by Franklin were underfilled and vice versa—essentially a difference of convention. Nevertheless, while Waitz was widely read, he never gained the amount of uptake seen with Franklin, whose theory was likened to his own. This suggests that the spread of Franklin’s account was not a function of these conceptual elements alone but must have drawn on something absent in Waitz.

References
— The strongest claims for Franklin’s originality stem from I. B. Cohen’s influential *Franklin and Newton* (300–309, 366–80). Heilbron’s assessment is more measured but nevertheless draws a stark contrast between Franklin’s theory and those of his predecessors, see Heilbron, *Electricity in the 17th and 18th Centuries*, 329, note 14.
— For discussion of Franklin’s predecessors and the views of contemporaries on his relation to prior work, see pages 13–16.

— For additional notes on the parallels between Waitz and Franklin's theories, see the Appendix, "The Explanatory Resources of Franklin and Waitz's Accounts."

2) Franklin's theoretical exposition was more direct than his predecessors'.

Explanation

One of the most striking points of divergence between Franklin's work and that of previous electricians concerns his treatment of theory. In the decades prior, theory was far less emphasized in electrical research than exploration and fact gathering, in part because the area was still in a state of flux. Where theoretical speculations were present, they typically presented as inductively formed propositions following a series of freestanding experiments. In his *Experiments and Observations*, however, Franklin adopts a style of presentation informed by his journalistic practice, one that is direct and presents ideas by order of importance and generality. His basic postulates are stated explicitly and at the outset instead of being woven into post facto interpretation, and most of the experiments discussed are clearly interpretable as tests of the proposal's claims. This shift in emphasis rendered the theory more legible, particularly to the uninitiated, and going forward, it helped to establish hypothesis testing as a greater priority.

References

— On the centrality of exploratory over hypothesis-driven work in earlier work, see "The Discovery and Impact of the Leyden Jar," 18–23.
— For a discussion of Franklin's style of writing, see pages 17–23.
— For an illustration of Franklin's distinctive approach, see Franklin, *Experiments and Observations*, 1–9, 51–82.
— For an example of the older approach, see Wheler, "Some Electrical Experiments, regarding the Repulsive Force of Electrical Bodies," 99–102.

3) Franklin's theory was more streamlined.

Explanation

Another major difference between Franklin's approach and those of his predecessors was the way in which the former bracketed thorny or otherwise intractable physical problems. Although he and others went on to introduce a wealth of refinements, the core of Franklin's model deals with the charge of macroscopic objects and the accounting book operations of addition and subtraction that can be applied to them. More complicated questions of capillary forces, dissipation rates for different media, and the like were set aside, making the theory easier to learn and use than Waitz's, which contained quite a few elements that were, from the perspective of what was then testable, digressions. Franklin also showed a certain skill in what philosopher Mark Wilson terms "physics avoidance," the practice of circumventing intractable problems by abrupt shifts in formalism or modeling strategy. In Franklin's case, this is most clearly displayed in his treatment of glass, which avoided the (at the time) fraught topic of action at a distance by means of such a maneuver. By avoiding the topic, Franklin allowed progress to be made in other arenas and bought time on the more difficult question of distance forces, which received something like a resolution only decades later, with the early to mid 19th century development of field theories.

References
— On the contrast between Franklin's theoretical style and those of his predecessors, see pages 23–27.
— Examples of Franklin confronting and bracketing thorny issues may be found in Franklin, *Experiments and Observations*, 3–4, 59.
— For an examination of compartmentalizing maneuvers in contemporary physics and applied mathematics, see Wilson, *Physics Avoidance*, chapters 1–3.

4) The Leyden jar paved the way for the emergence of a major theory like Franklin's.

Explanation
In addition to the clarity and simplicity of Franklin's exposition, the theory benefited from at least three major shifts brought about by the Leyden jar. First, the discovery brought in a large number of new entrants to the field—individuals less likely to have strong theoretical commitments on the issue and more likely to appreciate a simple and direct exposition like Franklin's. Second and relatedly, the jar served to coordinate priorities. The study of electricity had been wide and relatively undirected prior to the discovery. Within months of the jar's creation, however, it had become the central focus of nearly every electrician in Europe. Research into other areas continued, but the new invention ensured that there was a particular set of phenomena that all electricians paid attention to and rated as extremely significant, creating an opening for the first person to propose a detailed explanation of its operations. Finally, as was discussed in the prior study on the Leyden jar, the device made electrical experiments more reliable and easier to execute, allowing for more compelling demonstrations and rendering the field more amenable to hypothesis testing of the kind needed to bolster a central organizing theory.

References
— See pages 27–31 for an overview of the jar's attentional impact.
— For the jar's material impacts see "The Discovery and Impact of the Leyden Jar," 27–30
— For data on the number of new entrants following the jar's discovery, see Kryzhanovsky, "An Application of Bibliometrics to the History of Electricity," 487–92.

5) **The lightning rod was likely the most significant experimental factor in the spread of Franklin's ideas, despite its tenuous connection to his theory.**

Explanation
Although the success of Franklin's experiments with the Leyden jar served to establish a reputation for him, the lightning rod was likely what cemented his position as the era's preeminent electrician. Before the rod's famous demonstration at Marly-la-ville in 1752, Franklin's work had received some notice. His letters had been read to the Royal Society and a few of his more entertaining experiments had even been performed for Louis XV. These did not suffice to elevate his status above those of other prominent experimenters, however. For the five years separating the first announcement of the theory and the lightning experiment, Franklin occupied a respectable but less than revolutionary position. After the lightning experiment, however, there was a rapid uptick in praise for the American and the discussion of his ideas. Ironically, however, the experiment's success was not clearly predicted by his theory; rather, it served to confirm a largely independent empirical generalization about the action of pointed bodies on electrified conductors. The largest source of support for the theory came from a discovery that Franklin admitted having no solid explanation for.

References
— See pages 36-37 for additional context.
— For Franklin's speculations on the mechanism underlying the rod, see Franklin, *Experiments and Observations*, 59.
— On the problems with Franklin's proposed mechanism, see Heilbron, *Electricity in the 17th and 18th Centuries*, 336.

6) **Franklinism as an enduring school of thought benefited substantially from cultural and political shifts taking place in the mid to late 18th century.**

Explanation
Over and above his reputation as an electrician, Franklin enjoyed an exceptional degree of cachet among Europe's intelligentsia. The American was celebrated by the likes of Diderot and Kant, with more than one observer claiming that he had lifted humanity to the level of the gods. In one instance, that of Franklin's acquaintance Erasmus Darwin, the philosopher is actually depicted as slaying vampires. Needless to say, such enthusiasm goes beyond what is commonly seen in cases of technical or scientific achievement. The reason for this, I argue, lies in Franklin's position relative to the prevailing political and cultural winds. Going into the latter half of the 18th century, natural philosophy, like its political counterpart, underwent a significant ideological realignment. Previously framed as an aristocratic activity directed toward broadly theological ends, the study of nature became increasingly secular and more strongly associated with the

rhetoric of humanism. The shift was particularly pronounced in the case of electricity, which had been viewed as a realm particularly close to the divine. In terms of symbolism, Franklin and his discoveries were almost ideally suited for those pushing the shift. The "free thinking" American and subsequent revolutionary stood in sharp contrast to the old guard, and the peculiar nature of the Marly experiment—its snatching of electric "fire" from the heavens—made it irresistible to those looking for a new Prometheus. He was naturally adopted by those seeking to further the shift, then. Franklin became a figure of partisan support, drawing extreme praise from the growing bloc of secular and liberal intellectuals. As in the case of Darwin a century later, his ideas went from a theory to an ism, fostering its spread and engendering firmer commitment from its supporters.

References

— See pages 36–43 for a fuller discussion of Franklin's political alignments.

— On the broad political shifts in late 18th-century natural philosophy, see Schaffer, "Natural Philosophy and Public Spectacle in the Eighteenth Century," 1–43.

— For a particularly effusive celebration of Franklin, see E. Darwin, *The Botanic Garden*, vol. II, Canto I, 383–98, Canto II, 349–70.

—For a discussion of French Enlightenment perceptions of Pennsylvania, see Philips, *The Good Quaker in French Legend*, chapters 3–4.