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Poor Richard's Leyden Jar: Electricity and economy in Franklinist France

If a Man casually exceeds, let him fast the next meal, and all may be well again.—Poor Richard's Almanack, 1742.¹

No gains without pains.—Poor Richard's Almanack, 1745.²

So wonderfully are these two states of Electricity, the plus and the minus, combined and balanced in this miraculous bottle!—Benjamin Franklin to Peter Collinson, 1 Sep 1747.³

COBBLESTONES WERE THE first thing Benjamin Franklin found to admire in France when he landed there in the summer of 1767: he liked the smoothness under the wagon wheels that bore him gently from Calais to Paris.

He praised also the rationality of the cobbles' Cartesian construction: because they were cubes, they could be turned when one side wore down and made as good as new. Only one cloud threatened the sunny view Franklin's comfortable journey afforded him of French efficiency: "the poor peasants complained to us grievously that they were obliged to work upon the roads full two months in the year, without being paid for their labor." The French cobblestones served Franklin well in more ways than one. During his first hours on French soil, they introduced him to a primary target of the Economists' program of reform, the feudal *corvée* that exacted free labor from landless subjects although, to be sure, he could scarcely credit their complaints. "Whether this is truth, or whether like Englishmen they grumble cause or no cause, I have not yet been fully able to inform myself."⁴

Franklin's early encounter with the *corvée* coincided with the burgeoning of his interest in political economy. Reciprocally, the French Economists, or "Physiocrats," as they named themselves in the year of Franklin's first visit, began to take a keen interest in Franklin. Their economic program rested upon a philosophy, partly natural and partly moral, which had many similarities to his.

Before his travels to France, Franklin's relations with the *philosophes* had been based entirely upon his electrical research.⁵ The Enlightenment taxonomy of disciplines, in which method more than subject provided the principles

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All translations in this article are my own except where otherwise indicated. The following abbreviations are used: *BFP*, *The papers of Benjamin Franklin*, ed. Leonard Labaree et al. (New Haven, 1959-); *MAS*, Académie des Sciences, Paris, *Mémoires*.

1. *Poor Richard, 1742. An Almanack for the Year of Christ 1742*. By Richard Sanders, Philom. Philadelphia: Printed and sold by B. Franklin, in *BFP*, 2 (1960), 340.

2. *Poor Richard, 1745. An Almanack for the Year of Christ 1745*. By Richard Sanders, Philom. Philadelphia: Printed and sold by B. Franklin, in *BFP*, 3 (1961), 6.

3. Franklin to Peter Collinson, 1 Sep 1747 in I.B. Cohen, ed., *Benjamin Franklin's experiments* (Cambridge, 1941), 181.

4. Franklin to Polly Stevenson, 14 Sep 1767, in *BFP*, 14, 251.

5. Alfred Owen Aldridge, *Franklin and his French contemporaries* (New York, 1957), 23.

of organization,⁶ encouraged this shift from electricity to economy. "Physiocracy" invoked the methodological union of moral and natural philosophy: it meant "rule of nature."⁷ The Physiocrats meant to harness the methods of natural philosophy to their new moral science. Franklin met them halfway, for he had been applying the methods of moral reasoning to his new natural science.

In this essay I examine continuities between Franklin's electrical science and his moralist arguments in order to propose that Franklinist natural philosophy was teleological, calling upon hypothetical purposes in nature, and that this teleology can explain its extraordinary popularity in France. My points of departure are I. Bernard Cohen's and J.L. Heilbron's studies of Franklin's science and its situation.

Cohen, who introduced Franklin's natural philosophy to historians of science in the 1950s, presented a "Newtonian" Franklin after the Newton of the *Opticks*, the empirical essayer and querist.⁸ Recently, Cohen has turned to the function of "science in...political thought" and has gathered examples in which Franklin and others exploited the natural sciences for discrete political purposes, from reputation-building to the supplying of demographical data.⁹ If Cohen's Franklin was heir to the inaugural tradition of modern science, and a founder of the modern practice of applying particular scientific results to well-defined political tasks, Heilbron's Franklin is an older-fashioned and more fluid character. He is portrayed by contrast with "the modern scientist" as "the natural philosopher of the Age of Reason." Among his defining characteristics are his "sporadic engagement with experiments and demonstrations, reliance on wide-ranging analogy...concern with...natural religion, and hope for utility."¹⁰

The Franklin I now propose, the teleologist electrician, had the Newtonian reputation that Cohen describes for the Enlightenment reasons that Heilbron lists. He was less a Newton than an Enlightenment "Newton," a term of praise in response to characteristics that often had only tenuous connections with Newton's own work.¹¹ Franklin's salient "Newtonian" characteristic, I

6. Peter Gay, *The Enlightenment: An interpretation* (New York, 1969), 2, 164.

7. Elizabeth Fox-Genovese, *The origins of physiocracy* (Ithaca, 1976), 9.

8. I. Bernard Cohen, *Franklin and Newton* (Philadelphia, 1956); *Benjamin Franklin's science* (Cambridge, 1990).

9. Cohen, *Science and the founding fathers. Science in the political thought of Thomas Jefferson, Benjamin Franklin and James Madison* (New York, 1995), 26-27, 150, 156-195.

10. J.L. Heilbron, "Franklin as an Enlightened natural philosopher," in J.A. Leo Lemay, ed., *Reappraising Benjamin Franklin. A bicentennial perspective* (Newark, 1993), 196-220, on 197.

11. Cf. Gerd Buchdahl, *The image of Newton and Locke in the Age of Enlightenment* (London, 1961), 2; Gay (ref. 6), 2, 134; Henry Guerlac, "Where the statue stood: Divergent loyalties to Newton in the eighteenth century," in *Essays and papers in the history of modern science* (Baltimore, 1977), 131-145, on 133; and Paul Hazard, *European thought in the eighteenth century, from Montesquieu to Lessing* (London), 137.

suggest, was his natural philosophical appeal to teleology. This will perhaps be surprising given Franklin's, and the *philosophes'*, reputation for pragmatism, and the preference of both Heilbron's and Cohen's Franklin for local utility over universal truth. But what has been called Franklin's pragmatism can itself be seen as an expression of his tendency toward teleology. By the middle of the 18th century, mechanical explanation had come, especially in France, to represent the universalizing spirit of grand philosophical systems. Franklin's appeal to purposes as causes, rather than merely to matter in motion, looked in that context like a pragmatic independence of the spirit of system.¹² Franklin the teleologist, Enlightenment heir to "Newtonianism," was the hero of a movement against philosophical mechanism and for a return to partially teleological explanations of nature.

A perennial question regarding France's love affair with Franklin has been why the results of his electrical experiments were greeted so differently in France and England. Cohen judges that the initial reception of Franklin's electrical experiments in England was just, but that "later, when the American Revolution had made Franklin unpopular with many of the people of England...it became fashionable to discount his achievement." Heilbron responds that throughout, the British reception of Franklin was "perfectly appropriate, neither cool nor hostile, and that it appears ungracious only when contrasted with the French." French enthusiasm, not British reticence, was the more peculiar response, and Heilbron traces it to the professional rivalries of Franklin's chief promoter in France.¹³

I begin with these rivalries, on the assumption that they can help to explain both Franklinism and its success in France. They direct me to an underlying philosophical struggle between a mechanistic philosophy that strictly separated efficient and final causation, and a movement to rejoin cause with purpose (§ 1). Franklin's fusion of pragmatism with teleology resonated with this very sore point in contemporary French philosophical discussion. I next examine how this basic philosophical conflict operated in the electrical debate between Franklinists and the followers of abbé Nollet (§ 2). In the Franklinists' performance in this debate, the *philosophes* found the model of a deeply satisfying resolution to their difficulties, a way of making a moralized picture of nature and calling it common sense. Later, having proven certain methods of moral reasoning by applying them to natural phenomena, they were able to represent their moral and political arguments as natural science (§

12. Franklin himself was therefore able to represent the destruction of philosophical systems as central to his new science: "how many pretty Systems do we build which we soon find ourselves oblig'd to destroy!" Franklin to Peter Collinson, 14 Aug 1747, in *BFP*, 3, 171.

13. Cohen, *Franklin's science* (ref. 8), 96; Heilbron, "Franklin, Haller and Franklinist history," *Isis*, 68 (1977), 539-549, on 546-548.

3). Franklinism gave the *philosophes* the best of both worlds: modern empiricism and traditional metaphysics, a moralized natural science and a naturalized politics, a New World tale with some Old World lessons.

1. POOR RICHARD'S SCIENTIFIC METHOD

When the disputatious naturalist Comte de Buffon had Franklin's letters on electricity translated into French in 1752, he did so with an eye toward their uses in an ongoing argument.¹⁴ Believing that explanatory systems imposed an arbitrary and reductive logic on nature's plenty, he condemned as perniciously "systematic" an array of explanatory devices including Cartesian mechanism, mathematics, the Swedish botanist Carl Linnaeus's system of botanical taxonomy, and the entomological studies of his fellow naturalist René Antoine Ferchault de Réaumur. The prominence that Réaumur granted to structural regularities, such as the hexagonal perfection of beehive cells, gave Buffon a rhetorical opportunity to associate two evils, Réaumur and geometry, confirming the misguidedness of both.¹⁵ Franklin's relevance to Buffon's quarrel with Réaumur at first appears incidental. Franklin's account of electrical action contested the leading French theory, whose young author, the abbé Nollet, was a protégé of Réaumur's. By winning points against Nollet, Buffon indirectly triumphed over Réaumur.¹⁶ But Franklin's utility to Buffon's cause was actually substantial. Nollet's electrical mechanics represented just the sort of natural science Buffon disliked and Franklin's electrical teleology, the sort he promoted.

Nollet liked to call electricity the "action of a matter in motion" and "the effect of a mechanical cause." Since any given electrified body simultaneously attracted some objects and repelled others, Nollet reasoned, electrification must involve two streams of electrical fluid travelling in opposite directions, an "effluent" current carrying repelled objects away from the charged body, and an "affluent" current carrying attracted objects toward it. By the momentum and impact of this "double movement" Nollet claimed to be able to explain "all the known facts" about electricity. His crowning objection to Franklin's theory was that it lacked "truly physical causes."¹⁷

14. Concerning Buffon's role in the translation of Franklin's letters into French, see Heilbron, *The history of electricity in the 17th and 18th centuries* (Berkeley, 1979), 346–352; Jacques Roger, *Buffon: Un philosophe au Jardin du Roi* (Paris, 1989), 281–282; and Cohen, *Franklin's science* (ref. 8), 230n.

15. Georges Buffon, "Discours sur la nature des animaux" (1753), in *Oeuvres philosophiques de Buffon*, ed. Jean Piveteau (Paris, 1954), 317–350, on 347; *De la manière d'étudier et de traiter l'histoire naturelle* [1749] (Paris, 1954), 19–20, 22, 65; Roger (ref. 14), 122–123, 125, 255–257, 317–320.

16. Heilbron (ref. 14), 346–347.

17. Jean Antoine Nollet, *Lettres sur l'Electricité* (Paris, 1760–1775), 2, 13–14; "Conjectures

This was because Franklin did not attribute electrical effects primarily to the motion of a fluid. Instead he referred to the static presence or absence of electrical matter in bodies, to implicit distance forces, and to explicit natural purposes.

Franklin assumed two kinds of matter, common matter, which was mutually attractive, and electrical matter, mutually repulsive. These two matters also attracted one another, and each was required to balance the other in any ordinary object. In the event of too much electricity, the extra fluid pooled to form an active electrical "atmosphere." With little electricity, the unbalanced common matter became electrically active. Thus Franklin explained all signs of electricity by the "wanting" and "abounding" of electrical fluid in bodies.¹⁸ He saw in his electrical fire a source of answers to problems posed by a standard mechanics of matter in motion. This was bound to please Buffon.

In the first volume of his *Histoire naturelle, générale et particulière*, which had appeared in 1745, Buffon had criticized the philosophy of Nollet's mentor, Réaumur. In particular, Buffon disliked Réaumur's Cartesian assumption that life was imposed as a rational design upon brute matter and must be understood in terms of "simple inorganic parts." Deploring this reduction of life to lifelessness, Buffon claimed that each part of an organic being was homologous to the whole and that life inhered in matter itself. Its central processes, nutrition and reproduction, resulted from an internal "penetrating" force, an "active" self-perpetuating power. Buffon's collaborator, the abbé Needham, added that this vegetative power was a "continual excitation" resulting from "two simple and contrary forces, a force of resistance and a force of expansion."

In the late 1740s, Buffon and Needham tested their idea that matter was endowed with soul, consciousness, and a vegetative or reproductive tendency. In a series of experiments involving the microscopic study of mixtures including almond seeds, crushed wheat, and meat-juices, they claimed to have triggered spontaneous generation.¹⁹ Réaumur and his cabinet-keeper, Mathurin-Jacques Brisson, then spent the holidays of 1751 with the Jesuit naturalist J.A. Lelarge de Lignac. The three reproduced Buffon's and Needham's experiments in order to refute them. Afterwards Lignac, their chosen spokesman, brought out a three-volume attack on Buffon's natural history entitled *Lettres à un*

sur les causes de l'électricité des corps," in *MAS*, 1745, 107-151, on 107-18, 110, 139, 151; "Examen de deux questions concernans l'électricité," *MAS*, 1753, 475-502, on 492.

18. Franklin, "Opinions and conjectures" (1750), in Cohen (ref. 3), 213-236, on 213-218; Franklin to Collinson, 29 Apr 1749, *ibid.*, 187-200, on 188.

19. Buffon, *Histoire naturelle, générale et particulière* (Paris, 1750), 2, 7-9, 15-19, 28, 154-156; John Turberville Needham, *Nouvelles observations microscopiques* (Paris, 1747), xi, 190-198.

*Américain sur l'histoire générale et particulière de M. de Buffon.*²⁰

The disagreements between the two teams were basic. Réaumur, who always looked for the order in nature's design, responded to Buffon's and Needham's primordial stews by wondering "what agent will arrange this chaos."²¹ Buffon's principled distrust of rational systems, on the contrary, led him to rhapsodize Nature's "very disorders" as exciting his "whole admiration."²² This proved an influential sentiment. Louis Daubenton's anatomical descriptions of the King's cabinet accompanied Buffon's natural history and the *Encyclopédie* article "Cabinet," drawn largely from Daubenton's text, called nature "a state of sublime disorder."²³ Lignac regretted the Encyclopedic influence of Daubenton and his sublimely disorderly nature, and also dismissed Needham's contrary forces of resistance and expansion because, rather than opposing one another in proper Newtonian fashion, they summed to a positive "vegetative force." Buffon's belief that parts of an organism were homologous to the whole, such that a horse was made of infinite tiny horses, exhausted Lignac's patience.²⁴

By the end of 1751 the two sides were tied: Buffon, Daubenton, and Needham, against Réaumur, Nollet, and Lignac; three volumes of *Histoire naturelle* to three volumes of *Lettres à un Américain*; a sublimely messy, vitalist ontology versus a rationally ordered, mechanist one. Meanwhile Buffon had been preparing the revelation of his own American letter-writer. Franklin, like Buffon, believed in a monist suffusion of soul in matter. In the year of his first electrical experiments, he refuted Andrew Baxter's *An enquiry into the nature of the human soul*, in which Baxter described a Malebranchian dualist universe of passive matter and active, immaterial substance.²⁵ Franklin wrote that God's priority to all things must mean he had made the material world "out of his own Thinking immaterial Substance." In that case, substance must be essentially capable of thought; "if any part of Matter does not at present act and think, 'tis not from an Incapacity of its Nature but from positive Restraint."²⁶

20. Jean Torlais, *Un esprit encyclopédique en dehors de l'Encyclopédie. Réaumur d'après des documents inédits* (Paris, 1936), 238; Roger (ref. 14), 256; Joseph Adrien Lelarge de Lignac, *Lettres à un Américain sur l'histoire naturelle générale et particulière de M. de Buffon* (Hamburg, 1751).

21. Réaumur to Charles Bonnet, 14 Mar 1754 cited in Torlais (ref. 20), 243.

22. Buffon, *Manière* (ref. 15), 17.

23. "Cabinet," in Denis Diderot and Jean le Rond d'Alembert, eds., *Encyclopédie, ou Dictionnaire raisonné des sciences, des arts et des métiers* (Paris, 1751), 2, 489–493, on 490.

24. Lignac (ref. 20), Letter 10, 13, Letter 11, 12–14, Letter 12, 107, Letter 6, 6.

25. Andrew Baxter, *An enquiry into the nature of the human soul* [1737] (Bristol, 1990), 79–210; John W. Yolton, *Locke and French materialism* (Oxford, 1991), 163–164.

26. Franklin to Thomas Hopkinson?, 16 Oct 1746, in *BFP*, 3, 84–89.

Moreover, while Buffon had been mixing his vital concoctions, Franklin had been working to greater effect on his first electrical experiments. The "extremely subtle" matter described in Franklin's letters, like the force that infused living matter in Buffon's natural ontology, permeated common matter "with such ease and freedom as not to receive any perceptible resistance."²⁷ Franklin's electrical fire was particularly apt since Buffon had recently claimed that experimental physics had been misconstrued as the demonstration of mechanical effects. Instead, Buffon had argued, the true aim of experimental physics should be to explain "all of those things which we cannot measure by calculating."²⁸ Franklin's electrical matter did just that. It did not act by a standard mechanics of matter in motion, by momentum and impact. Instead it influenced the world it saturated by its own active properties. So for example Franklin invoked his electrical fluid to explain the perforations in a church vane that had been struck by lightning. These indicated that lightning was unlike a solid projectile, because it seemed not to have momentum but was "most easily turned to follow the Direction of good Conductors."²⁹ Similarly, Franklin proposed a "subtle elastic Fluid" for light, since if light consisted of material particles, their speed would give them the momentum of cannonballs.³⁰

Franklin's expansive electrical fluid and self-compressing common matter acted in ways that resembled the expansions and resistances of Buffon's and Needham's organic matter.³¹ Both were governed more by appetites than by forces, requiring one another, like the pairs of contrary elements in an Aristotelian compound, as hunger requires food.³² Buffon, who approved of Aristotle as a "better Physicist" than Plato,³³ had reason to admire Franklin's physics, and to find it familiar. A depletion of electrical fluid in common matter,

27. Buffon (ref. 19), 2, 17, 156; Franklin (ref. 18), 213-215.

28. Buffon (ref. 19), 18, 72-73. See also Diderot, "Art" (1751), in Alain Pons, ed., *Encyclopédie, ou Dictionnaire raisonnée des sciences, des arts et des métiers (articles choisis)* (Paris, 1986), 1, 247-257, on 252-253.

29. Franklin to Jan Ingenhousz, 21 June 1782 (dated by the Benjamin Franklin Papers Archive, Yale University), in Albert Henry Smyth, ed., *The writings of Benjamin Franklin* (New York, 1907), 7, 88-97, on 90-91.

30. Also, the sun would shrink as it gave off light, weakening its hold on the planets. Franklin to Cadwallader Colden, 14 May 1752, in *BFP*, 4, 310-312.

31. Heilbron ((ref. 14), 336-37) notes the non-mechanical mode of action of electrical atmospheres: "the static character of the atmospheres implied a step away from mechanism; only effluvia in motion can cause action by impact." Of the Franklinist avoidance of mechanistic explanations he writes that Franklinists "differed from their opponents in eschewing mechanical analogies to attraction and repulsion," *ibid.*, 367.

32. Aristotle, *On generation and corruption*, II.8, 335a5-335a15. Aristotle attributed "appetites" only to mind, and not to matter, but he did say that "food is akin to the matter, that which is fed is the 'figure',—i.e. the 'form'."

33. Buffon, "Systèmes sur la génération" [1749], in *Oeuvres* (ref. 15), 256-287, on 258.

like a scarcity of Buffon's nutritive material in a living body, resulted in a violent "hunger" to be filled.³⁴ Franklin's electrical appetites produced something like the continual excitation of Needham's organic ones, such that "common matter [was] a kind of sponge [sic] to the electrical fluid."³⁵

The active electrical "atmospheres" in Franklin's theory, the pooling of electrical overflow upon a body's surface resulting from an excess of fire within it,³⁶ also had an analogue in Buffon's theory of reproduction. When Buffon's animating fluid was present in greater abundance than was necessary for a body's nutrition, the excess was pooled in "reservoirs." The particles of animating fluid in these reservoirs, similar in form to the organism they comprised, were homunculi serving the purpose of reproduction.³⁷ In both Franklin's and Buffon's sciences, lack and excess, and a tendency toward balance and repletion, were the explanatory causes of activity, electrical in Franklin's case and nutritive and reproductive in Buffon's.

Buffon's vitalist ontology was accompanied by a calculus also suited to a purposeful world, and in this regard again, Franklin's science fit the bill. During the second half of the preceding century, rational theologians and natural philosophers had sought a happy medium between the twin dogmas of radical skepticism and scholastic certainty, and so had developed a tripartite division of probabilities into mathematical, physical, and moral. Accordingly, mathematical certainty was absolute and compelling, but unattainable in matters of natural philosophy, religion, and society. Here inferior forms of certainty, physical for natural philosophy, moral for religion and society, were sufficient.³⁸

Buffon's innovation, in order to suit probabilities even more closely to human purposes, was to eliminate mathematical certainty altogether, elevating moral certainty to its place. "The absolute, of whatever kind," he wrote in his essay on "Moral Arithmetic," "is of the domain neither of nature nor of the human mind." Absolute certainty resembled other abstract mathematical concepts like infinity. These were "privative ideas," arrived at by imagining a real object and then removing its sensible qualities; infinity was the removal of limits from a finite space. The habit of attributing positive existence to privative absolutes was, Buffon held, responsible for the gravest metaphysical

34. Franklin to Collinson, 1 Sep 1747, in Cohen (ref. 3), 181.

35. Franklin (ref. 18), 213-214.

36. *Ibid.*, 214.

37. Buffon (ref. 19), 2, 7, 154.

38. Lorraine Daston, *Classical probability in the Enlightenment* (Princeton, 1988), 56-57, 60; Barbara Shapiro, *Probability and certainty: A study in the relationships between natural science, religion, history, law and literature* (Princeton, 1983), 105, 32, 84, 4, 16, 31; Ian Hacking, *The emergence of probability: A philosophical study of early ideas about probability, induction and statistical inference* (Cambridge, 1975), 146.

mistakes, since "all our knowledge is founded upon proportions and comparisons, all is thus relation in the Universe." A calculus of moral probabilities would remedy these mistakes, and would have moral implications as well. "The Miser is like the Mathematician," Buffon wrote, "both estimate money by its numerical quantity," while the "sensible man" measures it only comparatively, in relation to its uses.³⁹

Buffon's probabilistic calculus, by yoking calculations to concrete purposes, was thus intended to bring moral as well as metaphysical benefits. It applied only to events within the purview of human expectations, defined according to the logic of associationist psychology: any probability that could be sensed, in this case by the emotions, fell within the domain of moral probability, while probabilities too small to affect the emotions were excluded. The calculus thus included a scale of moral probabilities calibrated by intensities of hope and fear, and bounded at either end by extremes of conviction and indifference. Since "of all moral probabilities, man is most affected by the fear of death," Buffon defined his scale according to this fear. A healthy man in the prime of life feels no fear of dying the next day. Buffon therefore defined the likelihood of such an event as the zero point of his scale. With the help of mortality tables, he concluded that all events with a physical probability below .0001 were morally impossible, and all events with a physical probability above certain.⁴⁰

There was opposition to Buffon's theory of probabilities, since those who hoped for a true reconciliation of the mathematics with the experience of probabilities saw no advantage in dismissing mathematical certainty.⁴¹ But Franklin's new science supported Buffon's controversial recommendations. In his *Autobiography*, Franklin confessed that he "twice failed" at learning arithmetic in school and "never proceeded far" with geometry. He also reported having early read Antoine Arnauld and Pierre Nicole's *La logique, ou l'art de penser* (1662), generally known as the Port Royal *Logique*.⁴² This was among the earliest accounts of quantitative probabilities and was important in establishing the epistemological category of moral certainty. Its authors sought to codify prudent and equitable risk-taking using a conception of "expectation" that combined the likelihood of an outcome with its value. It was prudent to take a risk if the unlikeliness of the favorable outcome was balanced by its favorability. Expectation thus included a qualitative component, the values of outcomes, with the quantifiable one, their likelihoods; Lorraine Daston writes

39. Buffon, "Essai d'arithmétique morale" (1777), in *Oeuvres* (ref. 15), 456-488, on 475-476, 484-486, 469.

40. *Ibid.*, 457, 459-469.

41. Daston (ref. 38), 77.

42. Franklin, *Autobiography*, in Smyth (ref. 29), I, 221-439, on 243.

that the Port Royal discussion was "as remarkable for its restrictions on quantitative reasoning as for its use of it." Indeed the Port Royal authors cautioned against an undue devotion to mathematical precision. Like Buffon later would, they identified a leading cause of errors in the mistaking of probabilities for realities.⁴³

Franklin knew this model of a calculus combining qualitative assessments with quantitative reckoning and he too liked to mix judgement with measurement. In a letter of friendly advice to Joseph Priestley, he devised a "Moral or prudential algebra" to govern choices in the face of uncertainty. This algebra involved making a list of pros and cons, "endeavor[ing] to estimate their respective Weights," and then using them to cancel one another until they revealed "where the Ballance lies." Franklin confessed that the "Weight of Reasons cannot be taken with the Precision of Algebraic Quantities." The value of the exercise lay not in the individual weights but in their comparison.⁴⁴ In his electrical theory, too, Franklin aspired to a kind of certainty that might well be called moral, in Buffon's sense of the word. Professing not to "clothe" his "Nonsense...in algebra, or adorn it with fluxions,"⁴⁵ Franklin used quantities in just the way Buffon preferred. They described sensible qualities, never mathematical abstractions. They presented relations rather than individual measurements. Often they represented states of balance and imbalance. Describing the conservation of charge in a condenser, for example, Franklin said its top could be electrified positively only in exact proportion as its bottom was electrified negatively. Suppose, he explained, that "the common quantity of electricity in each part of the bottle...is equal to twenty." In that case, one could electrify the top only as far as forty, since the bottom would then be at zero.⁴⁶

Franklin's use of geometry was also moral in this specialized sense: he used figures not for their geometrical properties, but to portray sensible qualities, like wetness or electrification. Franklin frequently surmised that mutually repulsive particles—either of electricity or of air—formed equilateral triangles. Air particles were held in triangles by gravity and electrical particles by their attraction to common matter. The smaller the triangles of electrical fire, the higher the degree of electrification. The wetter the air, the smaller the triangles.⁴⁷ The geometrical properties of triangles were irrelevant; Franklin used triangles merely to represent greater and lesser concentrations. For this moral

43. Daston (ref. 38), 17–18, 39, 243.

44. Franklin to Joseph Priestley, 19 Sep 1772, in *BFP*, 19, 299–300.

45. Franklin to John Perkins, 4 Feb 1753, in *BFP*, 4, 429–442, on 442.

46. Franklin to Collinson, 1 Sep 1747, in Cohen (ref. 3), 189.

47. Franklin, "Thunder-gusts" (1749), in Cohen (ref. 3), 201–211, on 203; "Opinions and conjectures," *ibid.*, 215; "Meteorological observations" (1751?), in *BFP*, 4, 235–243, on 235–236.

approximation of geometrical reasoning, Franklin was rebuked in an anonymous pamphlet on "his Pretensions to the title of NATURAL PHILOSOPHER:"⁴⁸

[I] shall just take a little notice of your method of introducing Mathematics. You certainly are not so ignorant as to imagine that it was in this manner that Newton applied Mathematics to explain Natural Philosophy?..He introduces no figures from which he does not deduce consequences; and what is more, the very figure he introduces is the only one which could have answered his purpose; whereas, for any use you make of your *triangles*, any other figure would have done your business equally well.

To Buffon, this tempering of quantitative reckoning by qualitative judgement surely proved that Franklin was an *homme sensé*, neither Mathematician nor Miser. Franklin's application of moral methods to natural science—his appeal to teleological argument and his promiscuous mixing of quantities and qualities—itself had pronounced moral implications. Christian grace was not eliminated from the *philosophes'* Heavenly City, wrote Carl Becker, but only translated into virtue.⁴⁹ In an example of this translation of grace to virtue, Joseph Priestley affirmed that nothing could "easily exceed the vain-glory, self-conceit, arrogance" of rationalist philosophers, and discerned in Franklin an unequaled "diffidence," a "modesty with which...[he] proposes every hypothesis."⁵⁰ The particular virtue by which the *philosophes* associated naive empiricism with saintly humility can best be described as philosophical modesty, and Franklin, by the *mélange* with which he replaced mechanical explanation, came quickly to personify it.⁵¹

48. *A Letter to Benjamin Franklin* (Oxford, 1777), in Cohen (ref. 3), 422–435, on 435. Shape, as opposed to geometry, was also instrumental in Franklin's account of how electrical fire could more easily be drawn from the pointed than from the smooth parts of bodies. To explain the power of points to attract and dispel electrical fire Franklin invoked the smaller surface area in communication with a point on a pointed protrusion than with a point on a flat surface. The reduction in proximate surface area meant a local minimum of force between common matter and electricity. Once again, although he referred to a triangle with labelled vertices, Franklin called upon no geometrical properties beyond the sensible property of pointiness. Franklin (ref. 3), 215–219.

49. Carl L. Becker, *The heavenly city of the eighteenth century philosophers* (New Haven, 1932), 49, 80.

50. Joseph Priestley, *The history and present state of electricity* (London, 1775; reprinted New York, 1966), I, xxvi [here Priestley is citing David Hartley], 192–193; see also 2, 15–16, 39–40, 56.

51. Keith Baker describes a great "chorus in denunciation of the 'spirit of system' and in praise of...epistemological modesty," in *Condorcet: From natural philosophy to social mathematics* (Chicago, 1975), 87. Gay similarly characterizes the "Enlightenment's campaign against system-building and in behalf of 'philosophical modesty,'" in Gay (ref. 6), 138–139. Cf. *ibid.*, I, 143–144, 178–179; 2, 134–135.

Franklin was ostentatiously diffident. He frequently drew the same connection as Priestley between philosophical method and social virtue. In his *Autobiography*, he reports having retained from Xenophon's *Memorabilia* of Socrates the lesson that self-improvement requires social intercourse and therefore adopted "the habit of expressing myself in terms of modest diffidence." This meant avoiding words like "certainly, undoubtedly," which provoke "modest men...to leave you in the possession" of your errors. Franklin professed to sprinkle his discourse with disclaimers like "*I should think it so*," or "*I imagine it to be so*," and cleaved to the pronoun "we" in his accounts of the Philadelphian experiments.⁵² In his moral writings, he had long argued for a link between social solidarity and philosophical modesty. An interlocutor in the 1735 "Dialogue between two Presbyterians," having denied papal infallibility, concludes that he cannot "modestly claim Infallibility" for his own interpretations of scripture, and must choose unity over orthodoxy.⁵³ A decade later, Franklin presented the new science of electricity as the product of the same union of method and virtue: "If there is no Use discover'd of Electricity," he wrote, "*it may help to make a vain man humble.*"⁵⁴

A contemporary French philosophical and political development was in perfect affinity with these principles: Encyclopedism. Denis Diderot devised his *Encyclopédie* to be the embodiment of epistemological modesty tied to social collaboration. Because it was not "given to a single man to know all that can be known," an Encyclopedia could never be "the work of a single man," or a single learned academy, or yet of the combined efforts of all the societies and academies. It required authors "spread throughout the different classes," the artisan *homme du peuple* and the *savant* alike. Philosophical modesty founded an Encyclopedic community permeating all corners of human society.⁵⁵ Rationalist certainty, in contrast, was arrogant and solipsistic. Franklin, like Diderot and Buffon, associated unsociable arrogance with the spirit of system, and especially with mathematics. He tells us in his *Autobiography* that Thomas Godfrey, the only mathematical member of his Philadelphian club for "mutual improvement" in the pursuit of "Morals, Politics or Natural Philosophy," the Junto, was "not a pleasing companion; as, like most mathematicians I have met with, he was forever denying or distinguishing upon trifles, to the disturbance of all conversation. He soon left us." Godfrey

52. Franklin, *Autobiography* (1771-1788) (ref. 42), 169, 171, 244-245; Franklin to Collinson, 28 Mar 1747 and 11 Jul 1747, in Cohen (ref. 3), 169, 171. Franklin also carefully segregated his scientific writing into "experiments and observations" on the one hand and "opinions," "conjectures," "suppositions," or "loose thoughts" on the other, professing to treat facts as facts and fantasies as fantasies. See Franklin to Perkins, 13 Aug 1752, in *BFP*, 4, 340-341.

53. Franklin, "Dialogue between two Presbyterians [1735]," in *BFP*, 2, 27-33.

54. Franklin to Collinson, 14 Aug 1747, in Cohen (ref. 3), 171.

55. Diderot, "Encyclopédie [1755]," in Pons (ref. 28), 2, 40-67, on 51, 44-45, 64, 49.

left behind a gathering of artisans worthy of the *Encyclopédie*: a copier, a surveyor, a shoemaker, a joiner, several printers, a clerk, and, finally, one gentleman, an expert in the art of punning.⁵⁶

In place of quantification and mechanization, proponents of philosophical modesty recommended common sense and analogy. Buffon referred to a "common sense" in its Aristotelian sense, as an "internal" faculty that integrated the sensations.⁵⁷ "Common sense" is defined in Voltaire's *Dictionnaire philosophique* as "good sense, coarse reason." When men invented this expression, Voltaire tells us, they "expressed the opinion that nothing enters into the soul except by the senses."⁵⁸ Diderot's *Encyclopédie* article "Bon-sens" explains that "good sense supposes experience...it is the faculty of deducing from experiences." This faculty was so homely that one could boast of it without vanity.⁵⁹ That promoters of common sense should have approved of Franklin's philosophy is no surprise: he has since come traditionally to personify common sense. But the meaning of the phrase has evolved away from its Enlightenment emphasis upon the five senses as the source of all reliable knowledge, and denigration of "hypotheses," in the specialized sense of mechanist idealizations.⁶⁰

Though he frequently declared his abhorrence of them,⁶¹ Franklin did rely heavily upon hypotheses in the general sense. The directionality of electrical flow is a good example. "We know that electrical fluid is *in* common matter," Franklin reasoned, "because we can pump it *out*" by using a spinning globe generator or by rubbing a glass tube.⁶² Sparks caused by contact between an emptied and an over-filled body showed the restoration of equilibrium. They were the electrical fire travelling from the replete to the depleted body. Yet sparks do not demonstrate directionality. Only Franklin's theory of electrical transfer led him to surmise that a spinning globe was provoked, by the rubbing of the cushion, to take in electrical fire, and therefore was over-filled, or positively charged.⁶³

56. Franklin, *Autobiography* (ref. 42), 298-299.

57. Roger (ref. 14); Aristotle, *De anima* III.2, 425b15-425b20; Buffon (ref. 15), 323.

58. François Marie Arouet de Voltaire, "Sens commun," in Voltaire, *Dictionnaire philosophique* [1764], ed. René Pomeau (Paris, 1964), 351-353.

59. Diderot, "Bon-sens" [1751], in Diderot and d'Alembert, *Encyclopédie* (ref. 23), vol. 2, 320-329, on 329.

60. The Abbé de la Roche credited Franklin with a "healthy reason" and a "solidity of thought." These hale qualities made Franklin prefer a "well-observed fact to all abstract reasoning not founded in nature or truths of experience." Abbé de la Roche, "Fragments d'une vie de Franklin," Bibliothèque de l'Institut de France, MSS 2222, 72-73.

61. Franklin to Perkins, 13 Aug 1752 in Smyth (ref. 29), 3, 96; Franklin to abbé Soulavie, 22 Sep 1782, *ibid.*, 8, 597-603, on 601; Franklin to unknown correspondent, 14 June 1783, *ibid.*, 9, 52-53.

62. Franklin (ref. 18), 214.

63. Franklin to Collinson, 11 Jul 1747 in Cohen (ref. 3), 175.

Franklin acknowledged this lack of empirical support for positivity and negativity in an account of his research into the charge on thunder clouds. Having charged one glass phial from a spinning globe generator and the other through a lightning rod, he hung a cork ball between them, and by its oscillation concluded that they were differently charged. On the assumption that the globe was positive, he concluded that thunder clouds must be negative. This meant that "in thunder-strokes, 'tis the earth that strikes into the clouds, and not the clouds that strike into the earth." This piece of counter-intuition, Franklin said, would not trouble the experienced electrician, who would understand that whether the clouds were positive and the earth negative or *vice versa*, there would ensue "the same explosion, and the same flash between one cloud and another, and between the clouds and mountains, &c., and same rending of trees, walls, &c., which the electric fluid meets in its passage, and the same fatal shock to animal bodies."⁶⁴

Despite their independence of empirical evidence, the hypotheses of negative and positive electricity were permissible as common-sense because Franklin did not abstract from sensory experience in presenting and defending them. On the contrary, he appealed to sensations as his primary arguments. Showing the "wonderful effect of pointed bodies" in drawing off and throwing off electrical fire, he noted that in the dark one could see the fire "continually running out silently at the point." Likewise smoke from dry rosin on hot iron was attracted to form atmospheres around positively electrified objects, "making them look beautifully, somewhat like some of the figures of *Burnet's* or *Whiston's theory of the earth*."⁶⁵ What Franklin called a flow of electrical fluid looked like a glow and the atmospheres were formed by smoke, not electrical fire. Neither fluid nor atmosphere was itself visible. But Franklin's arguments on their behalf were illustrations, and this made them common sense.

Cartesian-style mechanism had shut teleological considerations out of natural philosophy. Common sense, by sharply constraining mechanist speculation, allowed teleology back in and privileged speculative purposes over hypothetical efficient causes. Franklin used a common sense argument-by-illustration in the service of his teleological understanding of the conservation of charge. He dramatized the tendency of different electrical states toward equilibrium, when allowed communication through a conductor, by making a cork ball oscillate between two wires, one attached to the positively charged top of a condenser, the other to its negatively charged bottom. Rather than

64. Franklin to Collinson, Sep 1753, in Cohen (ref. 3), 271.

65. Franklin to Collinson, 11 Jul 1747 (ref. 63), 173. Later Franklin ((ref. 3), 216) used the same means to demonstrate that electrical atmospheres followed the shape of the bodies they surrounded.

attributing the oscillation to the motions of the electrical fluid as it carried the cork along in its path, Franklin did the reverse. He attributed the motion of the fluid to the motion of the cork, investing the cork with the purpose of equalizing the two electrical states, "fetch[ing] and carry[ing] fire from the top to the bottom" of the bottle. This tangible transaction, the cork's industrious fetching and carrying, had no mechanical cause, nor did it need one to constitute common sense. It needed only to be made apparent.⁶⁶

Analogical reasoning, like the common, internal sense, combined and integrated the testimony of the senses without abstracting from it, according to advocates of philosophical modesty. For all matters "falling not under the reach of our senses," Locke had written, "Analogy...is the only help we have."⁶⁷ Buffon affirmed this opinion: "If experience is the foundation of all our physical and moral knowledge, analogy is its first instrument."⁶⁸ Diderot, in his article "Encyclopédie," explained that his chief Encyclopedic purpose, to "change the common manner of thought," resided in the "analogical" *renvois* at the ends of the articles. These became emblematic of the Encyclopedic project, not least because its critics so deplored them. They were, one wrote, "eternal and oppressive...drag[ging] the reader alphabetically, from letter to letter, from page to page, from column to column."⁶⁹

Even d'Alembert, having resigned his co-editorship of the *Encyclopédie*, parodied the examples Diderot had offered of the utility of analogical "proofs." Analogies were indifferent to causation; thus one might use analogical reasoning to "prove" that a barometer rises to announce rain.⁷⁰ But Diderot stood by his *renvois*, insisting that by relating the articles to one another, "interlacing the branches [of the tree of knowledge] with the trunk," they sent the reader "to places one would never be guided except by analogy."⁷¹ Franklin's chief propagandist, Priestley, also agreed that "analogy is our best guide in all philosophical investigations," and hoped his *History of electricity* would persuade electricians to follow Franklin's example in part by "deducing one thing from another by means of analogy."⁷² Franklin was a bold analogist,⁷³ linking the cushion and globe of his electrical generator to

66. Franklin to Collinson, 1 Sep 1747 (ref. 3), 183.

67. John Locke, *An essay concerning human understanding* [1689], ed. Peter H. Nidditch (Oxford, 1975), 665.

68. Buffon (ref. 39), 457, and *Manière* (ref. 15), 62.

69. Simon-Nicolas-Henri Linguet, *Annales politiques*, 11 (1784), 370.

70. D'Alembert, *Essai sur les éléments de la philosophie de Newton* [1759] (Hildesheim, 1965), 90; John Pappas, "L'esprit de finesse contre l'esprit de géométrie: Un débat entre Diderot et d'Alembert," in *Studies on Voltaire and the 18th Century*, 89 (1972), 1229-1253.

71. Diderot, "Encyclopédie" (ref. 55), 54-56.

72. Priestley (ref. 50), 2 13, 54-56.

73. Heilbron ((ref. 10), 196) has written of Franklin that "the spring of his creativity lay in the play of his great power of analogy across all the arts and sciences."

the water and salt in the ocean, which ostensibly rubbed together to generate lightning and electricity. When a simple experiment (the shaking of a vial of salt water) failed to confirm this hypothesis, he extended the analogy to the friction of the wind against hills and trees.⁷⁴

Analogy, like common sense, privileged teleological over mechanist speculation. Rather than yielding individual causal explanations, analogy projected resonating patterns of balance and harmony throughout the natural and moral worlds. As Heilbron has shown, the concept of electrical charge as a surplus or deficit of electricity, measured against a neutral, balanced condition, parallels the argument of Franklin's *Dissertation on liberty and necessity* of 1725. Here Franklin had supposed that when "a Creature is form'd and endu'd with Life, 'tis suppos'd to receive a Capacity of the Sensation of Uneasiness or Pain." The creature's desire to be freed from pain was the "Spring and Cause of all Action;" life was a succession of escapes from discomfort. These escapes caused pleasure, and, since "the *Desire* of being freed from Uneasiness is equal to the *Uneasiness*, and the *Pleasure* of satisfying that desire equal to the *Desire*, the *Pleasure* thereby produc'd must necessarily be equal to the *Uneasiness* or *Pain* which produces it."⁷⁵ Though Franklin "later repudiated this doctrine, as useless or mischievous...he by no means abandoned its form," but applied the same bookkeeping to myriad other subjects. "Franklin's difficulty in conceiving of accumulation without compensatory deficits," writes Heilbron, "indicates the strength of the habitual mode of thought that created the concepts of plus and minus electricity."⁷⁶

Electrically charged objects moved from one place to another in order to restore an equal distribution, never mind what carried them, affording an "occasion of adoring that wisdom which has made all things by weight and measure!"⁷⁷ Nollet deemed this teleology a perversion of good Newtonian philosophy. In response to the Italian Franklinist Giambattista Beccaria's invocation of Newton to justify a physics of motions without mechanical causes, Nollet wrote: "I find the rule of Newton very good, Reverend Father, as long as one does not abuse it." But for him Beccaria's proposal to explain electrical attraction by the need of full bodies to give, and of empty bodies to receive electrical matter, represented a clear abuse of Newton's example. "If I saw an inanimate object move itself toward another, for the sole reason that it lacked what the other could give it, I would believe I had seen a miracle."⁷⁸

74. Franklin, "Thunder-gusts [1749]," in Cohen (ref. 3), 202-203; Franklin to Collinson, Sep 1753, *ibid.*, 267-268.

75. Franklin, "Dissertation on liberty and necessity [1725]," in *BFP*, 1, 57-71.

76. Heilbron (ref. 10), 208.

77. Franklin (ref. 18), 214-215.

78. Nollet, *Lettres* (ref. 17), 2, 161-162.

Franklin's reputation as an electrician benefitted more by the lightning rod experiment at Marly-la-Ville in May 1752 than by any other single event. Yet the analogy between lightning and electricity neither relied upon, nor especially supported, Franklin's account of electrical action. Indeed, as Nollet protested, he himself had proposed this analogy several years earlier.⁷⁹ As for seizing the lightning from the heavens, Jacques de Romas, a Nolletist electrician in Bordeaux, obtained certificates of priority for the electrical kite experiment from the Bordeaux Academy of Sciences and also ultimately from the Paris Academy. Romas probably conceived of a sort of lightning rod and submitted the idea to a notable member of the Bordeaux Academy, the baron de Montesquieu, the year before the Marly experiment. Romas employed effluvia to explain the lightning rod, claiming that the effluences from the electrified rod forced back the effluences from the thunder clouds.⁸⁰ This account, if unsatisfactory, was no more so than Franklin's. Franklinist advocates of lightning rods remained unable to explain how points both attracted and dispelled electrical fire and to decide whether one or the other (or both) of these powers was instrumental in protecting civilization from lightning.⁸¹ It was not the lightning rod experiment, therefore, that made the reputation of Franklin's theory in France.⁸² Priestley gleefully suggested a different factor: "Dr. Franklin's...reputation was greatly increased by the opposition which the Abbé Nollet made to his theory."⁸³ This opposition lent Franklin's experiments a significance that transcended the electrical debate. They began to represent not just a theory of electricity, but a kind of natural philosophy.

79. Jean Torlais, *Un physicien au siècle des lumières. L'Abbé Nollet. 1700-1770* (Paris, 1954), 112-113; "Au reste, mon amy, s'il cela confirme et il soit prouvé par là que le tonnerre et l'électricité sont au fond la meme chose, ouvrez mes lecons de physique 374 et vous verez que je l'ay dit 4 ans avant l'homme à qui l'on s'efforce d'attribuer cette idée," Nollet to Jean Jallabert, 2 June 1752, in Nollet, *Correspondance entre l'abbé Nollet et le physicien genevois Jean Jallabert*, ed. Isaac Benguigui (Geneva, n.d.), 216. See Heilbron (ref. 14), 351.

80. Years later, Montesquieu kindly reported to Romas that Franklin had toasted Romas' health at dinner one evening. This was the best gratification Romas would receive, and he duly recounted it to his wife. "Nothing pleases me more," she responded, "than this enthusiasm of our English savants." Jacques Romas, *Oeuvres inédites de J. de Romas...avec une notice biographique et bibliographique par Paul Courteault*, ed. J. Bergonie (Bordeaux, 1911), 289, 73, 183-185. See also Archives de l'Académie des Sciences, dossier Le Roy.

81. "Thus the pointed rod either prevents a stroke from the cloud, or, if a stroke is made, conducts it to the earth." Franklin, "Of lightning, and the method (now used in America) of securing buildings and persons from its mischievous effects," Sep 1767, in Cohen (ref. 3), 388-392, on 391.

82. Roderick Home, "Electricity in France in the post-Franklin era [1974]," in Congrès International d'Histoire des Sciences, 1974. *Actes, II* (1975), 269-272.

83. Priestley (ref. 50), I, 193; Heilbron (ref. 13), 548; Cohen, *Franklin and Newton* (ref. 8), 511.

In the year of Franklin's first visit to France, Priestley noted that in many philosophical journals "the terms Franklinism, Franklinist and the Franklinian system occur[ed] on almost every page."⁸⁴ Nollet observed sarcastically that Franklin was the "Evangelist of the day."⁸⁵ A couple of years later, urging Franklin to return to France for a second visit, one devoted sectarian promised him that he would be "amid franklinists." This disciple signed his letter "Bertier Frankliniste," and added piously: "I was a franklinist without knowing it, and now that I know I never fail to cite the author of my sect, Sir."⁸⁶ Franklin's particular claims about electricity, for example, the power of points to transmit electrical fluid, or the impermeability of glass to its flow, were not beliefs of a sort to hold unconsciously. Bertier must have had in mind not the particulars of Franklin's account of electricity, but the approach to natural philosophy he took them to embody. In this way, Bertier's avowal reflected a widely shared sentiment. Franklin's French readers immediately perceived the relevance of his electrical theory to the urgent philosophical conflict between a mechanist natural philosophy that separated efficient from final causation and a teleological natural philosophy that united them.

2. POOR RICHARD APPLIED

The 1752 translation of Franklin's letters on electricity, fostered by Buffon, made a great sensation. The following year Diderot promoted Franklinism as a model of how to avoid doubling nature's veil with metaphysics: "Open the works of Franklin...and you will see how the experimental art demands sight, imagination, wisdom, resourcefulness."⁸⁷ Diderot argued that only "instinct"—"looking, tasting, touching, listening"—could break beyond the confines of rationalist solipsism and presented seven "conjectures" as examples of sensationist, instinctual natural philosophy. The first was a preformationist account of reproduction involving homunculi like Buffon's and Needham's. The second, third, and fourth conjectures involved the use of Franklinist electrical fire to explain phenomena like crystallization and the aurora borealis.⁸⁸

Where electrical matters were concerned, before Franklin's intervention the community of *philosophes* was fairly peaceful.⁸⁹ But in 1753, the *Histoire* of the Academy of Sciences reported that the subject of electricity had recently

84. Priestley (ref. 50), 1, 193.

85. Nollet, *Lettres* (ref. 17), 1, 10.

86. Joseph-Etienne Bertier to Franklin, 27 Feb 1769, in *BFP*, 16, 56.

87. Diderot, "De l'interprétation de la nature [1753]," in Paul Vernière, ed., *Oeuvres philosophiques de Diderot* (Paris, 1956), 165–245, on 217.

88. *Ibid.*, 185, 198–214.

89. Heilbron (ref. 14), 288.

come to mark an apparently unbreachable rift among *physiciens*.⁹⁰ "The bitterness of the quarrel between Nollet and Franklin," Cohen writes in *Franklin and Newton*, reflected "a profound chasm between the metaphysical bases of two theories: the Cartesian and the Newtonian."⁹¹ But the first factor in making Franklin a Newton was the contrasting assessment of Nollet as a Descartes.

Descartes and Newton (and Nollet and Franklin) were symbolic antagonists more than actual ones.⁹² Alexandre Koyré traced this symbolic antagonism to Newton's own insistence upon it and argued that Newton's representation of himself as Descartes' opposite did not make it so. Newton was the first of a tradition of Newtonians to oversimplify the matter: central elements of his physics were "directly influenced by Descartes," and even "profoundly Cartesian."⁹³ Peter Gay has described how the *philosophes* drew, meanwhile, upon Newton's representation of Descartes as "his supreme, almost his sole opponent," in order to "construct a Descartes who was the ideal type of the rash metaphysician."⁹⁴ At the heart of this ideal type, according to Koyré, lay the rejection of a "materialism that banished from natural philosophy all teleological considerations."⁹⁵ The difference that drove Enlightenment conventions of Newtonianism and Cartesianism had primarily to do neither with empiricism, nor with rationalism, nor with materialism, nor with mechanism, but with purpose. Here was an important though slender difference: Descartes had exiled purposes from natural philosophy on principle; Newton had reluctantly left a crucial gap where his disciples could fill in the metaphysics of their choosing.

Enlightenment eulogists of Newton's mechanical system showed a remarkable tendency to cite its breaches. An example is Hume's satisfaction that though Newton "seemed to draw off the veil from some of the mysteries of nature" he also demonstrated "the imperfections of the mechanical philosophy," restoring Nature's secrets "to that obscurity in which they ever did and ever will remain."⁹⁶ Voltaire, in his *Lettres philosophiques*, popularized for a

90. "Sur l'électricité," in *MAS*, 1753, 6.

91. Cohen (ref. 8), 387.

92. Ref. 11.

93. Alexandre Koyré, "Newton et Descartes," in *Etudes Newtoniennes* (Paris, 1968), 85-242, on 103, 109. Guerlac ((ref. 11), 73) wrote that "[i]nsofar as there existed throughout the [18th] century such a commonly held 'world view' as... 'Newtonian philosophy'... it would seem to owe as much to Descartes, and to other influences from the previous century, as it does to Newton." See also Roderick Home, "Out of the Newtonian straitjacket: Alternative approaches to eighteenth century physical sciences [1979]," in *Studies in the eighteenth century, IV: Papers presented at the fourth David Nichol Smith Memorial Seminar, Canberra, 1976*, eds. R.F. Bassenden and J.C. Eade (Canberra, 1979), 235-249.

94. Gay (ref. 6), 2, 147.

95. Koyré (ref. 93), 127.

96. David Hume, *The history of England from the invasion of Julius Caesar to the abdication of James the Second, 1688* [1780] (Boston 1856), 6, 374.

French audience the contrast between Newton's heroic acceptance, and Descartes' dogmatic refusal, of obscurity.⁹⁷ Newton had set the standard for philosophical modesty by abstaining from giving gravity a mechanical cause.⁹⁸ Descartes, carried by his materialism to his fantastic plenum of whirlpools and eddies, had set the standard for philosophical arrogance.⁹⁹ Following this paradigm of philosophical conflict, Franklinists said Nollet was vain and opinionated, that he blocked the growth of knowledge by seeking "to explain everything" mechanically.¹⁰⁰ Nolletists responded by accusing Franklinists of "Pyrrhonism" and "misplaced moralizing."¹⁰¹

More to the point, Nollet himself had disavowed Cartesianism. He rejected the vortices of electrical matter announced by Cartesian electricians, notably Fontenelle and Nollet's own teacher, Dufay. Nollet replaced the vortices with rectilinear currents. Furthermore, his reason for rejecting Cartesian vortices in the case of electrical matter was empirical. In experiments, Nollet saw small objects moving to and from an electrified body in radial, diverging, and converging lines. When he approached other bodies to the electrified ones, Nollet saw the electrical matter itself leave the electrified body in little "tufts" of diverging rays.¹⁰² These were more direct empirical evidence than Franklin's observations of smoky "electrical" atmospheres. Nevertheless, Nollet was destined to play Descartes to Franklin's Newton: his emphasis upon matter, motion, and complete mechanical causation identified him as a Cartesian despite his disavowal and departures, while his accusation that Franklin's explanations lacked mechanical causes helped to identify Franklin as a Newtonian.

Newton had demurred from offering an efficient cause for gravitational attraction, and Franklin offered none for his distance forces of electrical

97. Voltaire, *Letters concerning the English nation* [1733], ed. Nicholas Cronk (Oxford, 1994), 61–66, 74.

98. Gay (ref. 6), 2, 133–136.

99. Koyré, (ref. 93), 88, 115, 361–362.

100. Joseph Aignan Sigaud de la Fond, *Précis historique et expérimental des phénomènes électriques, depuis l'origine jusqu'à ce jour* (Paris, 1788), xii, 115.

101. Abbé Durand, *Le Franklinisme réfuté, ou remarques sur la théorie de l'électricité l'occasion du système de plusieurs physiciens sur ce sujet* (Paris, 1788), 9–10.

102. Nollet, *Leçons de physique expérimentale*, 5th edn. (Paris, 1759–66), I, xx–xxi; *Essai sur l'électricité des corps* (Paris, 1746), 67–80. "It is in fact impossible to class Nollet and his fellow French experimental physicists meaningfully as either Cartesian or Newtonian." Thus Home, "The notion of experimental physics in early 18th century France," in Joseph C. Pitt, ed., *Change and progress in modern science* (University of Western Ontario Series in Philosophy of Science, 27 (1985)), 107–131, on 111. See also Home, "Nollet and Boerhaave: A note on eighteenth century ideas about electricity and fire," in *Annals of science*, 36 (1979), 171–176; and Heilbron (ref. 14), 276–77. Empirical observation of the "divergent jets were the foundation, and very likely the immediate inspiration of the système Nollet;" Heilbron, *ibid.*, 283.

attraction and repulsion. He never used attraction or repulsion to represent the direction of flow of electrical matter, and never attributed the motion of attracted and repelled objects to the motion of the electrical fluid. Even when he used the oscillation of a cork ball between the positive top and negative bottom of a condenser to demonstrate the equalization of charge, as noted above, he assumed that the cork ball carried the electrical fluid rather than *vice versa*.¹⁰³ In fact, though, in his tolerance for incomplete mechanical explanations, Franklin went far beyond Newton. Newton had left a causal gap at the crux of his system; but Franklin put purposes in place of material causes throughout his. Newton had made a show of accepting that he could not explain gravitational attraction, the phenomenon upon which his physical system rested. But Franklin focused his electrical science altogether elsewhere than upon electrical attraction and repulsion, being more interested in the qualities of the electrical fluid itself.

Attraction and repulsion, which had directed the early study of electricity, lent themselves to mechanist effluvial theories, with effluent and affluent fluids carrying attracted and repelled bodies in the required directions. But Franklin dismissed effluvia and used attracted and repelled objects merely as signs of electrification. Even then, he preferred the more fiery variety of signs, such as sparks and glows. Priestley, translating Franklinist practice into doctrine, said attraction and repulsion constituted poor empirical evidence. In a phrase that recalled Diderot's celebration of the "looking, tasting, touching, and listening" instinct,¹⁰⁴ Priestley wrote that the effluvial theories' days were numbered when electricity began "to make itself sensible to the smell, the sight, the touch and the hearing: when bodies were not only attracted and repelled, but made to emit strong sparks of fire, . . . a considerable noise, a painful sensation, and a strong phosphoreal smell."¹⁰⁵

The Franklinist reliance upon sparks and glows, so much at odds with all previous assumptions about the importance of attraction and repulsion, looked to Nollet like deliberate provocation. He responded with exasperated disbelief that there was a certain "affectation in rejecting attraction and repulsion as equivocal signs."¹⁰⁶ In Nollet's view, Franklin pushed aside what should have been at the very center of his science, electrical motions. He focused instead upon flashes and winds and vapors, and moreover, attributed these to static surpluses and deficits of fire. Nollet protested that electrical matter could explain nothing on its own, just as "the air is not the wind." Matter itself

103. Franklin to Collinson, 1 Sep 1747 and 29 Apr 1749, in Cohen (ref. 3), 185, 189; Home, "Franklin's electrical atmospheres," in *British journal for the history of science*, 6 (1972), 131-151, on 133; Heilbron (ref. 14), 336-37, 366-367.

104. Diderot (ref. 87).

105. Priestley (ref. 50), 15, 16, 18.

106. Nollet, "Examen" (ref. 17), 487.

constituted no explanation; it had to be set in motion. Franklin confused "the subject with its modifications." The electrical "virtue" inhered, not in the fluid itself, but in the fluid's "movements."¹⁰⁷ Moreover, attention to these movements revealed fatal flaws in Franklin's theory. How could a body repel things by receiving matter, as Franklin's theory implied a negatively charged body must do? How could a body attract things by giving forth fluid, as a Franklinist positive body must? More generally, how could a single current "cause movements opposite to its own?"¹⁰⁸ Nollet pronounced Franklinism conceptually incoherent: it confused effects with causes and accidents with necessities, and above all, it conflated matter and motion.¹⁰⁹

Franklin's own supporters, as Nollet was quick to point out, recognized these inconsistencies and missing mechanisms in their theory.¹¹⁰ But in their most successful responses, they did not try to resolve the contradictions of their system. Instead they bolstered Franklin's arguments by more of the same: experimental displays, homely analogies, and assumptions of nature's purposeful maintenance of a state of balance.

The effects of negative electricity posed the gravest conceptual problem for Franklinist theory.¹¹¹ True, Newton had declined to give gravity a cause, but neither had he hinted at so mysterious a cause as a negativity. In fact, Franklinist explanations in terms of negative and positive electricity were not even internally consistent. F.U.T. Aepinus, an ambivalent Franklinist at the Berlin Academy of Sciences, pointed out that if ordinary matter attracts electricity, and electricity repels itself, neutrally charged bodies, containing a balance of normal and electrical matter, should attract one another. The electrical matter in each would attract the common matter in the other, overwhelming the mutual repulsion of the electrical matter in each. Unless, Aepinus speculated, common matter was mutually electrically repulsive as well. That would have the advantage of explaining minus-minus repulsion, though it would have the disadvantage of reversing Newton.¹¹²

More generally, it was "difficult to imagine" how negative electricity could cause the various phenomena of electrification, that is, how a lack of something could cause anything. This was especially problematic in the case of the mutual repulsion of two negative bodies, for how could two absences repel one another?¹¹³ The Philadelphian Franklinist Cadwallader Colden was

107. Nollet, "Réponse au supplément d'un mémoire lû à l'académie par M. le Roy," *MAS*, 1753, 503-14, on 511.

108. Nollet, "Examen" (ref. 17), 486.

109. Nollet, *Lettres* (ref. 17), 3, 159-60, 243.

110. Nollet, "Examen" (ref. 17), 481.

111. Heilbron (ref. 14), 337.

112. Heilbron (*ibid.*), 388-89 and (ref. 13), 548-49.

113. Jean-Baptiste Le Roy, "Memoire sur l'électricité," *MAS*, 1753, 447-74, on 449-50.

troubled by this difficulty and Franklin's "Meteorological observations," addressed as a response to Colden, opens with the confession "that it seems absurd to suppose that something can act where it is not."¹¹⁴ Ebenezer Kinnersley, another Philadelphian, wrote to Franklin proposing to do away with repulsion altogether, and to explain all apparent instances of it by "the mutual attraction of the natural quantity [of electricity] in the air, and that which is denser or rarer" in electrified bodies.¹¹⁵ Franklin agreed with equanimity that minus-minus repulsion was "difficult to be explained," and indeed that "attraction seems in itself as unintelligible as repulsion."¹¹⁶

But he did not labor to resolve this unintelligibility, nor, often, did his followers. A notable example is Jean-Baptiste Le Roy, the leading French Franklinist electrician, who showed great versatility in elaborating upon Franklin's own original logic to respond to Nolletist challenges. Franklin had initially established the existence of symmetrical electrical states by the appearance of two intensities of sparks, stronger ones between negatively and positively charged bodies, and weaker ones between either and a neutral body.¹¹⁷ Le Roy improved upon these initial displays to show that the glass globe of an insulated generator became electrified symmetrically to its framework, the globe positively and the framework negatively. The sparks that the globe and framework gave one another were twice as great as the sparks they gave to a person on the floor.¹¹⁸ Furthermore, if either the globe or the framework were grounded, sparks from the other to a person on the floor were greater, which supported Franklin's balance hypothesis that more electricity could be fed into the positive side of the apparatus as more could be drawn from the negative side, and vice versa.

Next Le Roy went beyond spark-intensities to reveal symmetry by means of glows and brushes of fire. Rods presented to the conductor and framework by one end, and to one another by the other, showed a brush of fire on the conductor side and a glowing point on the framework side. Le Roy surmised that the electrical fire converged to a glowing point on its way into a rod, and diverged in a brush as it exited.¹¹⁹ Thus the brush showed fire moving out of

114. Franklin to C. Colden, 6 Dec 1753, in *BFP*, 5, 144-47, on 145.

115. Ebenezer Kinnersley to Franklin, 12 Mar 1761, in Cohen (ref. 3), 349-50.

116. Franklin to Kinnersley, 20 Feb 1762, in Cohen (ref. 3), 365-366.

117. Franklin to Collinson, 11 Jul 1747, in Cohen (ref. 3), 175.

118. This observation had ambiguous implications, however. In principle, the amount of electricity exchanged between the positive globe and the negative framework should be the same as the amount exchanged between the positive globe and a grounded person: just the globe's excess electricity. Still, the greater effects exhibited between the two electrically charged parts of the apparatus did seem to suggest contrary states of electrification.

119. Nollet wrote, "Mr Leroy me prouve par des raisons qu'il appelle luy meme des raisons d'analogie, ... quil passe de la matiere Electrique dans les pointes ou l'on voit paroître un point lumineux." Archives de l'Académie des Sciences, dossier Nollet.

the over-full conductor, and the glow marked its entrance into the depleted framework.

On behalf of negative electricity itself, Le Roy again cited the sensible manifestations of the fluid, or rather, in this case, the absence of such manifestations. His tactic was to disprove that repulsion ever happened by means of a fluid in motion, even in the more intelligible set of cases that involved positive charges. He pointed out that one could feel no breath of wind, nor see any glow or flow of electrical matter between two mutually repulsive bodies. On the contrary, when two positive bodies were opposed to one another, they would make one another's visible brushes of electrical fire disappear "like snuffing out a candle." This absence of any sign of effluence between mutually repulsive bodies cast doubt, Le Roy argued, on the notion of a mechanical cause for repulsion.¹²⁰ Wind and sparks were, however, exactly the sort of evidence that Nollet distrusted as variable, unreliable impressions, because they indicated no directional flow of fluid. In response to Le Roy's argument he pointed out that there was indeed an undeniable sign of effluence between two electrified bodies: mutual repulsion itself.¹²¹

Finally, Le Roy tried an analogy. He suggested replacing the words "negative" and "positive" with "condensed" and "rarefied." Imagine a container covered by a piece of parchment. One could tear the parchment by rarefying the air inside the container as well as by condensing the air outside. So a rarefaction could indeed have the same effect as its opposite, a condensation of substance.¹²² Nollet responded that the analogy failed precisely because the parchment example was made intelligible by a mechanical cause that the phenomena of negative electricity obviously lacked. The parchment was torn, whether through condensation or rarefaction, by the pressure of the air outside the container. In many of the phenomena of negative electricity, in contrast, all effects had to be attributed to the depletion of electrical fire in an electrified body. Le Roy had been misled, Nollet reckoned, because he considered "electricity...as a virtue in itself, in abstraction from all mechanism."¹²³

If negative electricity required associating the same effects with opposite causes, the "power of points," Franklin's claim that pointed conductors could both attract and dispel electricity more easily than other shapes, involved the opposite problem: assigning opposite effects to the same cause. M.J. Brisson, a Nolletist electrician, took Franklin to task for his claim that points could "draw off" and "throw off" electrical fire. Brisson wondered how, if "the

120. Le Roy (ref. 113), 455-466.

121. Nollet, "Examen" (ref. 17), 500, 487.

122. Le Roy (ref. 113), 450.

123. Nollet, "Examen" (ref. 17), 492.

point of an electrized body has less force for attracting and retaining its atmosphere than has one of [its] sides...it [can] be that the point of a non-electrized body has more force than one of [its] sides?¹²⁴ To explain the apparent contradiction, Franklin argued by analogy. It requires less force to pluck out the hairs of a horse's tail one by one than all at once. By analogy, pointed conductors plucked small bits of electricity rather than large clumps; they could pick bits of electrical matter either from themselves, when throwing off fire, or from other objects when drawing off fire.¹²⁵

The methodological mix of displays, analogies and appeals to a purposeful natural world proved peculiarly effective when applied to the central apparatus of Franklinist philosophy, the Leyden jar, a glass jar filled with water into which (according to the prevailing theory) electrical matter was fed through a wire.¹²⁶ After the jar was charged, if one touched both the wire and the bottle at the same time, one received a massive shock. One could also draw sparks off the outer surface of the jar during charging. The mystery was that the jar had to be grounded, not insulated, during charging, in order to get a major explosion by discharging it. This seemed counterintuitive to those who thought like Nollet; if the jar was grounded, why did the electricity not all run out the bottom, since, as attraction across glass screens showed, glass was permeable to electrical matter? Why should the jar charge at all? Why should there be any electrical effects on the outer surface of the glass, let alone the violent commotion during the discharging?

Crucial to Franklin's account of the Leyden jar were his willingness to assign qualities to electrical and other substances with no (or with indifferent) mechanical justifications and his assumption that charge was conserved. The operative qualities were an alleged "springiness" of electrical matter and an inability to penetrate through glass. These caused the electrical fire to compress inside the bottle. Conservation of charge dictated that the surfeit of electricity inside it correspond with a symmetrical negativity on its outer surface: as much fluid could be fed into the inside as could be forced from the outside. Franklin explained the Leyden shock provocatively as the rush of the "abounding of fire" within the jar, which "presses violently" to ease the "hungry vacuum" without, where the "wanting" of fire "seems to attract as violently in order to be filled."¹²⁷

124. Mathurin Jacques Brisson, *Dictionnaire raisonné de physique* (Paris, an viii (1799–1800)), 87.

125. Even Franklin ((ref. 18), 219) immediately admitted the dubiousness of this account, yet "I do not cross [it] out: for even a bad solution read, and its faults discovered, has often given rise to a good one."

126. On the design of the Leyden jar, see W.D. Hackman, *Electricity from glass: The history of the frictional electrical machine 1600–1850* (Alphen aan den Rijn, 1978), chapt. 5.

127. Franklin to Collinson, 29 Apr 1749 (ref. 18), 188, and 1 Sep 1747 (ref. 3), 181.

Nollet objected that springiness was a "vexatious" supposition, which violated sound philosophical practice by multiplying hypotheses beyond, or even counter to, empirical evidence. A flexible electrical matter belied the "extreme speed" with which it made its effects felt.¹²⁸ Furthermore, for electricity to be compressed in electrified bodies, the bodies would have to be "vessels incapable of letting [the electrical matter] escape," which they clearly were not, since electrical effects could be transmitted through or across them.¹²⁹ Even allowing the electrical fluid its vexatious property of elasticity, the bouncing back of the fluid would not suffice to explain the Leyden effect, Nollet protested. Such a brusque, sharp sensation could only be caused by a collision, the impact of two streams moving in opposite directions, one from the wire and one from the bottle: "the spark bursts with a sort of precision," he insisted, "the inflammation, the noise and the pain...do not proceed by degrees...the effect is all that it can be in the instant it appears."¹³⁰ A uni-directional flow could never cause a sudden, sharp commotion. Nollet had no good answer to the central problem of how, if the jar were grounded and the glass permeable, there could be electrical effects on the sides of the bottle. But he maintained that Franklin's replete and hungry surfaces provided no mechanism for the effect.

As for the "alleged impermeability of glass," Nollet likewise rejected it "out of repugnance for useless objects and forced hypotheses."¹³¹ Impermeability was contradicted by observations of electrical effects between charged bodies separated by glass. It had the further problem of implying that all of the "great quantity of electrical emanations" from the Leyden jar's exterior surface originated there rather than in the generator. How could an uncharged surface be made to produce such a great quantity of electrical matter?¹³² Finally, there was no plausible reason why electrical fire should be able to move into and within glass but not through it. Franklin attempted an explanation of this difficulty, suggesting that the "texture [of glass] becomes closest in the middle, and forms a kind of partition, in which the pores are so narrow, that the particles of the electrical fluid, which enter both surfaces at the same time, cannot go through...yet their repellency can."¹³³ Even Franklin later rejected this hypothesis, having ground away more than half the thickness of a piece of glass and found it as good as before for making a condenser, a test also suggested by a Nolletist.¹³⁴

128. Nollet, *Lettres* (ref. 17), 2, 57; "Examen" (ref. 17), 494-495.

129. Nollet, *Lettres* (ref. 17), 2, 214-215.

130. Nollet, "Examen" (ref. 17), 489-490.

131. Nollet, *Lettres* (ref. 17), 3, 172-173.

132. Nollet, *Lettres* (ref. 17), 1, 71.

133. Franklin (ref. 18), 230.

134. Franklin to Dr. L???, 18 Mar 1755, in Cohen (ref. 3), 333; Romas (ref. 80), 138.

In defense of his account of the Leyden jar, Franklin characteristically offered an analogy that, although he confessed it did "not agree in every particular," would nevertheless clarify the jar's three most mysterious elements. These were, first, the "inconceivable quickness and violence" of the discharge; second, the strict symmetry between the positivity inside the jar and the negativity outside; and third, Franklin's contention that, owing to this symmetry, a charged jar had no more electricity in it than an uncharged one. Franklin asked his readers to imagine the jar as a bent spring. In order to restore itself to its natural configuration, a spring must symmetrically "contract that side which in the bending was extended, and extend that which was contracted." It must perform both operations simultaneously in order to perform either one. But despite the violence of the spring's snap, one would never dream of claiming that it had gained elasticity in the bending, or released it in the restoration.¹³⁵ This analogy was accompanied by Franklin's standard teleology. The outer surface of the Leyden jar emptied itself of electricity in order to maintain a balance with the inner surface, never mind how the particles of glass might be configured: "So wonderfully are these two states of electricity, the plus and the minus, combined and balanced in this miraculous bottle! situated and related to each other in a manner that I can by no means comprehend!"¹³⁶

The miraculous balance was experimentally indicated. Cadwallader Colden's son David, also a Franklinist, showed that the bottle could only be charged to a certain point. This limit implied that the jar could achieve a state of fullness such as Franklin described. But Colden did not supply, nor did he seek to supply, a mechanism to explain the jar's effects. At the end of his rejoinder to Nollet, therefore, Colden admitted that the Leyden jar, even as explained by Franklin, was "still a mystery not to be accounted for."¹³⁷ Sigaud de la Fond, sympathetic to the Franklinist program, likewise admitted "in good faith that [Franklin's theory] seems at first glance so paradoxical, that it can repel the mind of the reader." But he, too, embraced the contradictions of the Leyden jar. Though the idea of conservation seemed a paradox, "it is upon this paradox that Doctor Franklin's entire theory is founded...and it is this paradox that we propose...to establish as an incontestable truth."¹³⁸

The establishment of what appeared to be a paradox as an incontestable truth expressed an acceptance of the limits of mechanical explanation. It was also a rebuke to Cartesian arrogance. So too was the unexpected behavior of electricity; propagandists of philosophical modesty and common sense placed

135. Franklin to Collinson, 29 Apr 1749 (ref. 18), 190-191.

136. Franklin to Collinson, 1 Sep 1747 (ref. 3), 181.

137. David Colden, "Remarks on the Abbé Nollet's letters," in Cohen (ref. 3), 285-286, 290.

138. Sigaud de la Fond (ref. 100), x, 302.

a premium on accidents. Nollet was critical of the contemporary tendency to celebrate the unforeseen: "It is to chance, they say, that we owe a large part of our discoveries. I admit that this is true up to a point," but "chance presents itself indifferently to everyone," so its results must depend ultimately upon the philosopher's exploitation of it.¹³⁹ To Priestley, however, the exploitation of chance meant simply a readiness to be humbled by it. He found that electrical research had been cursed by the virulent "species of vanity" of its students, but complementarily blessed by its inclination to baffling, theory-defying accidents.

The electrical shock itself was a shock in all senses of the word, as "surprising" as any discovery of Newton's. And the Leyden phial, which had been invented entirely by mistake (its inventors unintentionally grounded their bottle though they assumed it ought to be isolated)¹⁴⁰ represented the pinnacle. It had defeated all pre-Franklinist theories "by exhibiting an astonishing appearance, which no electricians, with the help of any theory, could have foreseen."¹⁴¹ Priestley admired the Leyden jar and its celebrated interpreter for their strategic refusals to make complete sense.

3. MOTORS AND MOTIVES

Arguing about the epistemological limits of mechanics, the *philosophe*, Physiocratic sympathizer, and Finance Minister, A.M.R. Turgot, wrote to the marquis de Condorcet that impulsion could not account for the existence of movement in the universe, because it assumed a prior source of motion. To avoid an infinite regress, Turgot claimed, one needed to appeal to an ultimate teleology, a Prime Mover: "the only principle that experience shows to be productive of movement is the will of intelligent beings...which is determined not by motors, but by motives, not by mechanical causes, but by *final* causes."¹⁴²

Turgot and the Physiocrats had reason to be interested in the rivalry between Franklinism and Nolletism. Founding a moral science on the disputed authority of the natural sciences, judging that "nature did not limit her physical laws" to those traditionally studied, and being inspired to seek the "physical laws relating to society,"¹⁴³ they were attempting a similar

139. Nollet, *Leçons* (ref. 102), I, xxiii.

140. Heilbron (ref. 14), 312-316.

141. Priestley (ref. 50), 2, 20; I, xv, 192-193.

142. Anne Marie Robert Turgot to Marie-Jean-Antoine-Nicolas Caritat, marquis de Condorcet, 18 May 1774, in Charles Henry, ed., *Correspondance inédite de Condorcet et Turgot* (Paris, 1882), 172-173.

143. Pierre Samuel Dupont de Nemours, "De l'origine et du progrès d'une science nouvelle" [1768] in *Oeuvres politiques et économiques* (Nendeln, 1979), I, 523-611, on 536.

fusion of efficient with final causes. The problems and powers of Cartesian mechanism were central to the Physiocrats' program and to the surrounding debate. The Economists professed to be anti-Cartesian, overthrowing a model of causation they called arbitrary and capricious and bringing about a common recognition that the economy's complexity eluded mathematical reduction.¹⁴⁴ They opposed the calculations and mechanical manipulations of mercantilism, which they liked to insinuate was Cartesian economics. Instead they advocated suiting state policy to nature's own governance.¹⁴⁵ The primary natural purposes the Physiocrats cited were the same ones that drove Franklin's electrical economy: conservation and the maintenance of balance.

The Science, as the Physiocrats called their program of reform, taught that agriculture was the only truly productive part of the economy, meaning that it alone created more than it consumed. Elsewhere, value was conserved. Industry and commerce merely transformed values into equal values. Raw materials combined with labor equalled the resulting products; these were then exchanged for exactly their worth. Nature, through agriculture, was thus the original source of all the wealth in the economy.¹⁴⁶ This meant that taxes on commerce and industry were ultimately taxes on agriculture. Only nature herself could be taxed and, moreover, nature herself determined the true tax each year by creating an agricultural surplus, which Physiocrats called the "net product." In order to suit taxation to the annual increase in wealth following Nature's own rule, all taxes should be drawn directly from the agricultural net product. Taxes imposed upon any other part of the economy were arbitrary and destructive.¹⁴⁷ The practical implications of these principles consisted largely in the lesson that the landed proprietors' interests were the interests of all: their wealth must be maximized in order to maximize the nation's wealth. This chiefly meant the freeing of the grain trade, which the Physiocrats expected to bring about the "good," that is, high prices.¹⁴⁸

The Physiocrats understood their injunction that nature be allowed to determine taxation as the crux of an empiricist economic philosophy. They

144. *Ibid.*, 566, 577.

145. Anonymous, "De l'état actuel des Sciences et des Arts," in *Les ephemerides du citoyen, Ou bibliothèque raisonnée des sciences morales et politiques* (Paris, 1765), 2, t. 2, 220-221, 238; "Sur la prospérité des arts et du commerce," in *ibid.*, 3, t. 2, 266; "Réponse à l'Oeuvre intitulé Principes de tout Gouvernement," in *ibid.* (1767), 7, 143.

146. "Voilà le point essentiel et le plus ignoré ou du moins le plus négligé en France: on n'y a pas même reconnu la différence du produit des travaux qui ne rendent que le prix de la main-d'oeuvre, d'avec celui des travaux qui payent la main-d'oeuvre et qui procurent les revenus. Dans cette inattention on a préféré l'industrie à l'agriculture, et le commerce des ouvrages de fabrication au commerce des denrées du cru." François Quesnay, "Grains" [1757], in *François Quesnay et la physiocratie*, Vol. 2, *Textes annotés* (Paris, 1958), 459-510, on 472.

147. Dupont de Nemours (ref. 143), 550, 575-576.

148. Fox-Genovese (ref. 7), 58.

professed to replace abstractions with evidence. The economic historian Georges Weulersse has written that "there was hardly a word the Physiocrats used with greater frequency than the noun 'evidence,' the adjective 'evident,' and the adverb 'evidently.' Their whole moral philosophy, their whole politics rested upon the notion of evidence."¹⁴⁹ In a similar characterization of Economic Lockeanism, Steven Kaplan has described the Physiocratic program as the demand for "nothing less than a *tabula rasa* in subsistence affairs." The police apparatus designed to impose subsistence conditions was to be abandoned, and provisioning left solely to "nature" (that is, commerce).¹⁵⁰

"[I]f it has taken so much work to dissect the body politic," Quesnay assured his readers toward the end of his *Philosophie rurale*, "that does not mean we will need the scalpel in hand to maintain its health." The "spirit of regulation" had inflicted countless evils upon humanity by refusing to recognize "that the world goes on its own." When once the world was left alone, humanity would recognize the Physiocrats' "principles executed in virtue of the innate order of things. The government will have no care but to pave the way, remove the rocks from the path."¹⁵¹ To conceive their economic program as a natural science, the Physiocrats needed a purposive nature. Indeed, to identify the economy's innate order with nature's own dynamic process, they needed a nature whose purposes were identical with their economic program, a nature that distributed its several powers harmoniously.

Quesnay and his colleagues promoted a natural teleology that, like Franklin's moral and electrical credits and debits, maintained a dynamic equilibrium rather than a clockwork regularity, subordinating physical principles to moral purposes in its eternal return to balance and harmony. Pierre-Samuel Dupont de Nemours, leading Physiocrat and the coiner of the term, gave an explanation of the necessary symmetry of commercial exchanges that recalls Franklin's account of symmetry in the Leyden jar. "We will repeat incessantly," Dupont wrote, "that all trade assumes equilibrium, a balance of sales and purchases." Those who failed to understand this fact and tried to buy without selling, were lucky "that the thing is impossible."¹⁵² Buying and selling were inextricably associated as two sides of a single spring.

An hour before leaving London on his first trip to France, in a hurried last-minute note to his son William, Franklin wrote that he had been furnished with letters of introduction "to the Lord knows who. I am told I shall meet with great respect there; but winds change and perhaps it will be full as well

149. Georges Weulersse, *Le mouvement physiocratique en France* (Paris, 1910), 2, 120.

150. Steven Kaplan, *Bread, politics and political economy in the reign of Louis XV* (The Hague, 1976), 2, 682.

151. Quesnay, "Philosophie rurale" [1764], in *Quesnay* (ref. 146), 2, 687-728, on 727.

152. Dupont de Nemours, "De l'exportation et de l'importation des grains, mémoire lu à la Société royale d'agriculture de Soissons [1764]," in (ref. 143), 1, 61-246, on 162.

if I do not."¹⁵³ Despite his apprehensions, Franklin was not thrown upon the mercy of unversed strangers. Buffon, to his later chagrin, was absent from Paris during the whole of Franklin's stay.¹⁵⁴ But his efforts on behalf of Franklin's electrical writings had given rise to a sect of partisans. These *franklinistes* awaited their master with open arms, if Franklin's effusive thank-you notes of 1768 are reliable indicators.¹⁵⁵ They also provided a service beyond enthusiastic hospitality: they offered a social and intellectual bridge from Franklin's older interest in electricity to his more recent interest in political economy. *Franklinistes* began to recruit the moralist natural philosopher into the project of founding a naturalist moral science.

The Economists were intrigued by Franklin's electrical economy, though not naively. They had training in natural philosophy and experience in electrical research. An important example is the Physiocrat Jacques Barbeu-Dubourg, who was a physician, medical reformer, botanist, and mathematician as well as an electrical experimenter. In the last capacity Dubourg had presented his compliments to Franklin through Thomas François Dalibard, Franklin's original French translator, as early as 1754. Sometime after Franklin's visit Dubourg was inspired to add translation and editing to his list of vocations and avocations, volunteering himself to become Franklin's French editor. He published an edition of Franklin's works that included both electrical and political economic writings.¹⁵⁶ Dupont de Nemours soon introduced himself to Franklin in a letter that reflected Dubourg's success as Franklin's publicist: "I had known you as...the Physicist, the man whom nature allows to unveil her secrets...My friend Monsieur le Docteur Barbeu du Bourg has since communicated to me several of your writings concerning the affairs of your country."¹⁵⁷

Thus the electricians and Economists among Franklin's correspondents were friends, colleagues, and often, the very same people. When Franklin sent Dalibard a copy of Priestley's *History of electricity*, Dalibard responded by presenting Barbeu-Dubourg's compliments, and lamenting that Le Roy had made off with the *History* immediately upon its arrival.¹⁵⁸ Le Roy,

153. Franklin to William Franklin, 28 Aug 1767, in *BFP*, 14, 242-244, on 244.

154. Thomas-François Dalibard to Franklin, 14 June 1768, in *BFP*, 15, 141-142.

155. Franklin to Bertier, 31 Jan 1768, in *BFP*, 5, 33, and Franklin to Dalibard, 31 Jan 1768, *ibid.*, 35.

156. Jacques Barbeu-Dubourg, ed., *Oeuvres de M. Franklin* (Paris, 1773); Aldridge (ref. 5), 22; *BFP*, 15, 112-113; Dalibard to Franklin, 31 Mar 1754, in *BFP*, 5, 253-254.

157. Dupont de Nemours to Franklin, 10 May 1768, in *BFP*, 15, 118-119. Interest in electricity on the part of political economists was not limited to Physiocrats. The anti-Physiocratic Finance Minister Jacques Necker, who also rested his economic program upon a notion of social balance, performed a series of Leyden jar experiments and presented a memoir on them to the Académie des Sciences in 1761. Archives de l'Académie des Sciences, Procès-verbaux, 1761.

158. Dalibard to Franklin, 14 June 1768, in *BFP*, 15, 140.

meanwhile, began promiscuously to include economic problems along with electrical ones in his correspondence with Franklin preceding Franklin's second visit to Paris. Le Roy asked Franklin about the free exportation of grain and the advantages to be gleaned from competition. Franklin was initially reluctant to offer concrete answers to such queries, although he cautiously agreed with Le Roy that the "Principles of Commerce are yet but little Understood."¹⁵⁹ But when Priestley's *Essay on the first principles of government* was published, Franklin forwarded it to Barbeau-Dubourg.¹⁶⁰

The previous year, the Physiocrat's journal, the *Ephemerides*, had already announced Franklin's support for their cause.¹⁶¹ This announcement was followed by an account of Franklin's examination before the House of Commons during the Stamp Act controversy, during which he expressed no Physiocratic principles whatsoever.¹⁶² His argument concerned only the political, and not the natural or economic, basis for taxation. Dupont de Nemours, who had edited the volume in question, received a thorough scolding for this piece of name-dropping from Turgot: "to announce to the public the opinions of a man like Franklin," Turgot chided, "you must either be charged to do so, or be very sure of your facts. You are not yet cured of the sectarian spirit." It would have made for a more interesting article, Turgot suggested, to discuss "in detail the question of the colonies, carefully presenting the opinions of M. Franklin, which are not at all in accord with the true principles" of Physiocracy.¹⁶³

Franklin had then recently written two economic essays, but these were no more obviously physiocratic. In "On the price of corn and the management of the poor," he argued that it was discriminatory against farmers to allow the exportation of manufactured goods but not raw materials. The ban was publically justified as a measure to keep domestic prices down; Franklin interpreted this as "a tax for the maintenance of the poor" and objected that poverty was better eased by inducement than charity.¹⁶⁴ In "On the labouring poor," Franklin pursued this theme by condemning the Poor Law and more generally "the malignant censure some writers have bestowed upon the rich for their

159. Franklin to Le Roy, 31 Jan 1769, in *BFP*, 16, 34-35.

160. Franklin to Barbeau-Dubourg, 22 Sep 1769, in *BFP*, 16, 205.

161. Ref. 145 (1768), 7, 32.

162. Franklin argued that taxes could not fairly be imposed upon a population by an assembly in which it was not represented. He was so un-physiocratic as to allow import taxes on the principle that these were payments for the service of maintaining the sea for safe travel. See "The examination of Doctor Benjamin Franklin &c., in the British House of Commons, relative to the repeal of the American Stamp Act, in 1766," in *BFP*, 13, 129-159.

163. Turgot to Dupont de Nemours, 5 Aug 1768, in *Oeuvres de Turgot et documents le concernant*, ed. Gustave Schelle (Paris, 1913), 3, 13.

164. Text of 29 Nov 1766, in *BFP*, 13, 510-516.

luxury and expensive living while the poor are starving, etc." After all, Franklin explained, "the rich do not work for one another." They hire the poor and buy the products of their labor. Thus all that the rich spend goes straight to the poor. Franklin concluded this application of his standard conservationist teleology with the observation that "Our labouring poor receive annually the whole revenue of the nation, and from us they can have no more."¹⁶⁵

So Franklin's economic views, though he opposed various forms of taxation and regulation, were surely not sufficiently Physiocratic to justify the Physiocrats' claiming him as their own. Nor can the Physiocrats have been tempted to appropriate Franklin for his renown as a moralist and statesman, since it was they themselves who first effected this transformation of Franklin's reputation in France.¹⁶⁶ But Franklin finally made good the Physiocrats' claim, and the promise they had gleaned from his electrical philosophy, in his "Positions to be examined," published the following year. Here Franklin argued that a nation could honestly acquire wealth only by "a continual Miracle wrought by the Hand of God," that is, agriculture. Manufacture could transform but never create value. Fair commerce, the exchange of equal values, was also transformative rather than productive.¹⁶⁷ This argument finally made explicit the central tenets of Physiocracy, which were that all economic value is natural in origin; that economic value is therefore subject to nature's own process of self-governance; and that human manipulation of the economy is thus either futile or destructive. The social and economic orders must be allowed to regulate themselves freely, so that the inscrutable but beneficent motives governing them could be realized, and nature's balance maintained.

When Franklin arrived in Paris for the third time in 1776, having taken a revolutionary stand on the question of colonial taxation, he was as much an Economist as an electrician. This new collaboration, like the older one, was mutually beneficial. While Franklin endorsed the Physiocrats' economic program, they now supported his political arguments. These were principally against checks and balances and in support of a unicameral legislature. The Physiocrats took these campaigns to be further applications of Franklin's philosophically modest skepticism about mechanical arrangements. La Rochefoucauld approved of the unicameral legislature as the political expression of Franklin's avoidance of systematic complexity. Bicameralism, with its "mechanical" system of checks and balances, was the spirit of system applied to governing. Quesnay deplored the "system of counterweights in

165. Text of April 1768, in *BFP*, 15, 103-107.

166. Aldridge (ref. 5), 15.

167. Franklin, "Positions to be examined," 4 Apr 1769, in *BFP*, 16, 107-109.

Indeed, this association between methods and morals had been nascent policy for a good part of that half-century. Farmers as well as *philosophes* had considered the connection between Franklinist physics and Physiocratic politics; provincials as well as Parisians had debated it. The connection had been sharply apparent in 1764, for example, when Dupont addressed the Société royale d'agriculture of Soissons. Dupont told the Society: "all is linked, all connects to the land, all is joined by secret chains, tokens of divine goodness and by an influence as rapid as electrical fire." He concluded that when "wealth spreads over a branch of cultivation, all the others feel the commotion."¹⁷⁶ By the time Physiocrats and other reformers argued during the Revolution that the economic and political balance should be modelled upon the flow of electricity, not the springs of a clock, France was well-acquainted with the science as well as the morals of Poor Richard.

176. Dupont de Nemours, "Grains" (ref. 146), 120-121.