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Reflection

PERPETUUM MOBILES AND ETERNITY

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If the nineteenth century fathered energy physics, Leibniz was its distant grandfather, as he argued relentlessly that a certain physical entity—*vis viva*, an early form of mechanical energy—is conserved in all interactions. This conservation entails that a certain kind of mechanism, sometimes called *perpetuum mobile*, is physically impossible. So it is of great interest to learn what Leibniz himself thought of it and how that relates to some broader themes in his thought, for example, the world's eternity.

Early modern physics was of two minds about the possibility of perpetuum mobiles, theoretical and practical, and Leibniz is no exception in this regard. His first pronouncements on the issue show him confident that perpetual motion is feasible. In a draft from 1671, he outlines a mechanism with movable parts of different materials—wood and lead—alternately falling and rising in water without end, due to their different specific densities.[1] During his effervescent years of discovery in Paris (1672–1676), Leibniz considers again the possibility of perpetuum mobiles.

1 See his manuscript "Perpetuum mobile" of June 14, 1671, in Leibniz, *Sämtliche Schriften und Briefe. Achte Reihe: Naturwissenschaftliche, medizinische und technische Schriften; Erster Band: 1668–1676*, ed. E. Knobloch (Berlin: Berlin-Brandenburgische Akademie der Wissenschaften, 2009), 554–561.

In unpublished notes, he examines two proposed designs. One, originating perhaps with an unknown inventor, he dismisses as unworkable, on account of internal friction between the parts, which would bring the mechanism to a halt. Another, apparently proposed by himself, he endorses as technically possible.[2] But it is a perpetuum mobile improperly so-called: it uses a steady supply of external energy, for example, from wind or running water, to power a cyclical mechanism.

In Paris, Leibniz meets Huygens, who introduces him to the new mechanics, including Torricelli's principle and his own discovery that in a system of *i* colliding particles, the total $m_i v_i^2$ remains constant throughout the interaction. These two elements will put Leibniz on the path to his great discovery, in the 1680s, that a certain type of physical efficacy—which he baptized "live force" (vis viva) and on which he erected "dynamics," a new science—is conserved in all mechanical processes. Leibniz henceforth ties his new basic principle—Conservation of *Vis Viva*—to the claim that a perpetuum mobile is impossible. However, the conceptual connection between these two ideas shifts as Leibniz's thought evolves. In his 1686 *Brevis demonstratio erroris memorabilis Cartesii*, Leibniz takes the impossibility of perpetuum mobiles as a basic axiom and uses it as a yardstick for the right concept of force. Descartes's allegedly falls short, as it allows for mechanical processes that increase motive force and hence can be used to power a perpetual motion. In the 1690s, the impossibility of perpetuum mobiles becomes a corollary of Conservation of *Vis Viva*, now a fundamental principle, itself justified by deeper, metaphysical principles, for example the equality of the full cause and the whole effect, as in Leibniz's unpublished *Dynamica de potentia et legibus naturae* (1689–1690).

2 See V. Kirsanov, "Leibniz in Paris," in *The Global and the Local: The History of Science and the Cultural integration of Europe*, ed. M. Kokowski (Krakow: 2008, 353–358.

In any event, from 1686 on, Leibniz is resolute that perpetuum mobiles are physically impossible. Yet in 1715, a certain Karl Elias Bessler comes forward, under the nom de plume Orffyreus, claiming to have invented a self-sustaining mechanism. Instead of dismissing him as a fraud, Leibniz encourages further study of Orffyreus's machine and declares: "he is one of my friends." Leibniz's disciple Christian Wolff does no better: though an ardent believer in Conservation of Vis Viva, which rules out perpetuum mobiles, Wolff too extols the study of Orffyreus's device: allegedly "philosophers no doubt will receive from [its study] new light, so as to know by it other hidden things." To be sure, the machine turned out to be an ingenious hoax, secretly powered from the outside by Orffyreus's acolytes from a chamber adjacent to it.[3]

Now, a closer look at Leibniz's usage of "perpetuum mobile" reveals an ambiguity—which likewise plagues much early modern discussion of the idea. First, a "physical" perpetuum mobile is an artificial setup in which the total quantity of "force" increases over time. Leibniz declares this sort of mechanism to be impossible, on account of vis viva, the exemplar of force, being conserved in the world. Second, on the other hand Leibniz in his exchange with Denis Papin mentions a "mathematical" perpetuum mobile: an idealized mechanism in which friction has been abstracted away.[4] These devices are perpetuum mobiles in the sense that, once set in motion, they would go on forever.[5] Such idealized machines are

3 Bessler described and advertised his invention in Bessler (1719). Leibniz discussed it briefly, endorsing Orffyreus, in Leibniz, *Nachgelassene Schriften physikalischen, mechanischen und technischen Inhalts*, ed. E. Gerland (Leipzig Teubner, 1906), 119–121. Wolff extolled the alleged philosophical merits of Orffyreus's mechanism in Wolff, *Mathematisches Lexicon* (Leipzig, 1716), 1042–1043. A brief account of the Orffyreus episode is in F. Klemm, "Vom Perpetuum mobile zum Energieprinzip," in F. Klemm and H. Schimank, *Julius Robert Mayer zum 150. Geburtstag* (Munich: R. Oldenbourg, 1965), 15–17.

4 See Gideon Freudenthal, "*Perpetuum Mobile*: The Leibniz-Papin Controversy," *Studies in History and Philosophy of Science* 33 (2002), 609.

5 An elementary example is a pendulum oscillating in a frictionless medium or in a vacuum. Another, closer to the spirit of Leibniz's *Brevis demonstratio*, is a perfectly elastic ball dropped from rest on a rigid surface in a vacuum.

fully in accord with Leibniz's metaphysical dynamics, insofar as they work either by perpetually converting actual vis viva into latent (i.e., kinetic energy into potential) and vice versa; or by circulating vis viva around the system, for example, as a Newton pendulum does. The more interesting question is, are such Leibnizian perpetuum mobiles ever instantiated in the natural world? Leibniz seems to think that at least one exists: the world itself. In his exchange with Clarke, he comes to reproach Newtonians for their theory of matter. That doctrine postulates hard atoms: *rigid, inelastic* bits of matter, which are peculiar in that they "destroy motion," as it were; speed—and so Leibnizian vis viva, a function of it—is lost in rigid-body collisions. The long-term yet predictable outcome of ever more Newtonian interactions is that as matter loses motion, the world will slow down or even grind to a halt. "God had not, it seems, sufficient foresight to make it a perpetual motion," Leibniz observes reproachfully of the universe according to Newton.[6] This consequence, however, Newton was glad to accept, thinking it showed God indispensable to a world that needs periodic rewinding. Leibniz, in contrast, thought his own cosmology—in which *all* matter is endowed with a *grand principe du ressort* and animated by a constant amount of vis viva—does better justice to God's craftsmanship. The Leibnizian cosmos allegedly needs no rewinding, as the relative motion of its parts are conserved, which makes it a physical analogue of Leibniz's mathematical perpetuum mobile. Thus, the world is an eternally self-moving machine.

Still, we have reasons to question this conclusion, from facts that even Leibniz knew. To see that, consider an insightful point Papin raised in his debate with Leibniz.[7] Leibniz had remarked, predictably, that the Cartesian measure of force, which Papin

6 Leibniz's First Letter to Clarke, sec. 4, in *The Leibniz-Clarke Correspondence*, ed. H. G. Alexander (Manchester: 1970), 11.

7 The definitive study of the exchange between Leibniz and Papin is Freudenthal, "*Perpetuum mobile*."

defended, entails the possibility of physical perpetuum mobiles, or mechanisms that increase force. In response, Papin accepted that force cannot be increased but objected that, sometimes, force may be *lost*; for instance, in inelastic collisions. To deflect this difficulty, Leibniz privately granted that it "is not impossible" to think that some motion "in the bodies before the collision has been transferred to an insensible matter," such that, though the motion of the colliding bodies themselves may not be conserved, "it is nevertheless conserved in the total universe by an exceptional contrivance of nature."[8] That may be so, but this move fails to solve a grave problem for Leibniz: some of this transferred motion is *lost forever*, in that it cannot be retransmitted from the insensible parts of matter back to the macroscopic bodies. Some motion, and thus some Leibnizian vis viva, is dissipated, or irreversibly transferred to the smallest parts. Over time, these losses accumulate, draining the motion out of the large-scale matter in the world, threatening Leibniz's system in two ways. First, bodies will grind to a halt relative to each other, just as a manmade machine does, on account of friction and drag.[9] Leibniz in fact knows that friction is the greatest impediment to the practical feasibility of self-sustaining mechanisms: as he examined a proposed perpetuum mobile in his Paris years, he noted with skepticism that friction "will considerably hinder the motion" of the machine's moving parts.[10] Put more generally, friction, drag, dampened oscillations, wear, material fatigue, and other dissipative factors threaten the Leibnizian perfection of this world—they turn

8 Leibniz, manuscript LH XXXV, 9, 7, pp. 24r–v, cited and translated in Freudenthal, "*Perpetuum mobile*," 623.

9 Drag forces become relevant at large scales in the Leibnizian cosmos, because he operates with a vortex theory of planetary motions, unlike Newton's gravitation theory of distant attraction across empty space. Though the Leibnizian ether in which planets swirl around is very thin, it is nevertheless a resisting medium, and motion through it generates drag forces, which dissipate speed.

10 Leibniz, manuscript LH XXXVII, 5, pp. 58–59r–v. For an account of the machine's design, see Kirsanov, "Leibniz in Paris," 355.

it from a perpetuum mobile into rattling machinery, with every turn jangling imperceptibly to a halt. Second, because of that, the variety of speeds—hence the individual values of vis viva in single bodies—diminishes in the world, thereby reducing the *varietates formarum* (diversity of forms), which for Leibniz is a mark of this world's perfection.[11] To put it in anachronistic language, Leibniz, as he discovered friction and other types of lost motion, came face to face with entropy but chose to look away, perhaps too dismayed to contemplate what it would do to his optimal, eternally, self-moving cosmos.

11 Leibniz claims that the "diversity of forms" is a criterion and mark of optimality for possible worlds in his 1697 *On the Ultimate Origination of Things*; see Leibniz, *Philosophical Essays*, ed. and trans. R. Ariew and D. Garber (Indianapolis: Hackett, 1989), 149–154.