Comment

Agency

M. Norton Wise

Abstract: In support of Frans van Lunteren's project for big-picture history organized around "mediating machines," these comments stress "mediation" as active agency in the world rather than as mere metaphor, on the view that this active agency underlies the potency of technologies as mediators, both between different domains of knowledge and between theories and things. Similarly important for this power is the diversity of the particular constructions that constitute mediators like "balances" or "engines." Diversity of meaning and action gives them their cultural reach, from mechanical contrivance to natural process to political ideology. An interesting question remains about how many mediating machines will suffice for the big picture of modernity over four centuries. Statistics, for example, might be a crucial addition. Another question concerns how to characterize the knowledge regime of a mediating machine. Van Lunteren chooses "information" for the computer. He might also have chosen "complexity," with different import for the character of postmodernity.

There is no knowledge without a technology of knowledge—or, in less grand terms, we require tools to think with. That belief appears to underlie Frans van Lunteren's big-picture view of the history of science, as it does my own. Even more concretely, we share the view that the history of modern Western science reveals only a few modes of investigating and knowing the world that have acquired widespread potency across many subject areas. It is this aspect that makes them suitable for a big-picture periodization. Van Lunteren at one point calls these technologies of knowledge "dominant knowledge regimes," which seems admirably to capture their role. And in specifying their function I am very pleased to see that he has developed the notion of "mediating machines." My comments derive from reflections on this idea over the years, most recently in a summary article on "How the World Works."[1]

"Mediating machines" gain their historiographic potency from the active role that technologies have played in interrelating different aspects of the world. It is useful to distinguish two senses of this mediation. One sense—"horizontal," perhaps—consists in interrelating different areas of knowledge on the same plane. That is the sense I took up in "Mediating Machines,"

M. Norton Wise is Distinguished Research Professor in the Department of History at UCLA. He has published widely in the history of physical science, from the eighteenth through the twentieth century, and has recently completed *Aesthetics, Industry, and Science: Hermann Helmholtz and the Berlin Physical Society* (Chicago, forthcoming). With Mary Morgan he has coedited a special issue of *Studies in History and Philosophy of Science* on "Narrative and Science" that is scheduled to appear in 2017. Department of History, UCLA, Los Angeles, California 90095, USA; nortonw@history.ucla.edu.

[1] M. Norton Wise, "Comment marche le monde?" in *Histoire des sciences et des savoirs*, ed. Dominique Pestre, Vol. 2: *Modernité et globalization*, ed. Kapil Raj and Otto Sibum (Paris: Seuil, 2015), pp. 182–201.

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concerning the way in which the steam engine mediated between political economy and natural philosophy in industrializing Britain. An additional "vertical" sense, developed in "Mediations: Enlightenment Balancing Acts, or the Technologies of Rationalism," concerns the way in which technologies interrelate theories and things, interrelate theories about the world with the things whose existence they require.[2] Thus the calorimeter "weighed," and thereby reified, the fluid that the caloric theory required. The two quite different forms of mediation, typically acting together, empower the knowledge regimes of Van Lunteren's big-picture history. They connect people pursuing different interests and they connect ideas with materials.

METAPHOR AND ACTION

With respect to both forms of mediation, perhaps the most important suggestion I can make toward strengthening Van Lunteren's account (and my own) would be to avoid the term "metaphor" for mediating machines. Not that the usage is incorrect; but it fades too easily into the perception of *mere* metaphor, thereby obscuring what I take to be the most important aspect of these technologies as mediators, their agency in the world. For example, in the case of the steam engine mediating between political economy and natural philosophy, the engine very actively powered the world they shared by producing work. From the political economy side, this production of work required analysis in terms of labor value, the measure of the value of commodities. From the natural philosophy side, it required analysis in terms of the dynamics of heat; and with that, work soon became the defining measure of the "energy" of any system whatsoever. Although labor value and energy did not necessarily refer directly to one another, they both referred to the all-important, work-producing agency of the engine in the partially overlapping domains of political economy and natural philosophy. "Metaphor" seems not adequately to capture this active role.

In the apparently more metaphorical cases of the "difference engine" and the "analytical engine," Charles Babbage expected the machines to generate real products, most simply the trigonometrical and logarithmic tables required for innumerable practical uses. Even expressions like "engine of deduction" and "engine of development," which were sometimes employed for the differential and integral calculus itself rather than any material machine, referred to the power of the calculus to crank out solutions to real-world problems in an efficient manner. In that sense the computing engine and the calculus were not merely *like* engines; they *were* engines. Reflections of this kind (especially when supported by such wide-ranging meanings as those contained in the eighteenth- and nineteenth-century entries on "engine" in the *Oxford English Dictionary*: microscope, air pump, cotton gin, catapult, the rack, fish trap, grindstone, loom, fire engine) suggest that "steam engine" should be thought of as one of many different kinds of (nonmetaphorical) engines, albeit one that became an epitome during the industrial revolution. "Engine" covered a diverse array of material and nonmaterial contrivances for systematic production, whose partially overlapping functions and meanings escape any single definition. But it is precisely this diversity that gives the engine as a mediating machine its historiographical (as well as historical) power.

MOSAIC

Similar remarks apply to the role of balances during the Enlightenment. Their significance attached to their action as instruments, as technologies of knowledge, whether material or not.

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[2] M. Norton Wise, "Mediating Machines," *Science in Context*, 1988, 2:77–113; and Wise, "Mediations: Enlightenment Balancing Acts, or the Technologies of Rationalism," in *World Changes: Thomas Kuhn and the Nature of Science*, ed. Paul Horwich (Cambridge, Mass.: MIT Press, 1993), pp. 207–256.

They identified natural states of the world as equilibrium states or states of equality: planetary orbits (Laplace), chemical reactions (Lavoisier), reason (Condillac and Condorcet), commodity markets (Smith), populations (Malthus), justice (Guillotin), and mechanical systems in general (Lagrange). But diversity rather than unity characterized this array. The balance was not a single concept but a network of interrelated technologies.

The stress on diversity rather than unity leads me to suggest that the big picture oriented around a mediating machine looks less like a general idea or a common skeleton than like a mosaic. Even better might be an analogy with Bruegel's famous depiction of the culture of a Netherlandish village in terms of a collection of its familiar proverbs. That is, the big picture consists of many smaller stories. It is necessarily superficial and cannot provide the meaning of its components, as though they were examples of it, for they in fact constitute it. The components retain their own identity and their own stories. This is an in-principle matter. It is only by working out details of the smaller stories that we can construct the big picture from their interrelations. In this task mediating machines can be of great value, for they help to show how interrelations across a broad spectrum actually function. This action is relatively straightforward in relating Lavoisier's chemical balance to his calorimeter as a balance, since both instruments actually functioned by weighing. More revealing are seemingly quite distant relations, such as that between the calorimeter and the guillotine, both labeled "*la machine*" and both conceived as balances, with the guillotine enforcing the ideal of class equality in executions. One of the most important features of mediating technologies, as in this case, is that they allow us to see in very concrete and active terms how social/political aspects of a period interrelate with more strictly "scientific" aspects.

COMPLETENESS

While many people may agree that mediating machines provide useful insights into the basic modes of investigating and knowing the world that have been prominent in Western society since the seventeenth century, there will probably be less agreement about what particular set of such "machines" can adequately cover the ground. In "How the World Works," with reference particularly to the physical sciences in the long nineteenth century, I have suggested that three overlapping periods with three main technologies can do much of the work: equilibrium dynamics (balances), temporal dynamics (engines), and statistical dynamics (statistical technologies). The statistical "machines" are crucial to big-picture history because they provided entirely new ways of understanding the world. They grounded statistical and probabilistic conceptions of such widely differing things as population, entropy, statistical causality, the electron as a statistical object, a species as a population or gene pool, and econometrics as a science. For that reason, the corresponding big picture has deserved the title "Probabilistic Revolution."[3]

There seem to be few additional moments of reconception and investigation of nature that can make a claim on late nineteenth-century science as broad and deep as this one. Evolution and the technical means of objectifying it is surely the most obvious candidate. One might also turn to electromagnetic technologies and to chemical synthesis, both of which did much to transform the world during the "Second Industrial Revolution." But this additive approach to completeness suggests that big-picture history might well benefit from thinking about mediating machines as complexes of technologies (electrical-chemical-statistical-evolutionary) whose interactions are critical to the dynamics of science and society. Such an approach would complicate the picture, but even for beginning students that may well be a good thing.

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[3] Wise, "Comment marche le monde?" (cit. n. 1); and Lorenz Krüger, Lorraine J. Daston, and Michael Heidelberger, eds., *The Probabilistic Revolution, 1800–1930*, 2 vols. (Cambridge, Mass.: MIT Press, 1986).

COMPUTERS

An issue of a somewhat different sort arises with respect to the computer as a mediating machine, just because there are multiple ways to conceive of its role in the big picture and there are various points of entry. Frans van Lunteren has focused on "information," which is a perfectly natural choice for all the reasons he cites. For quite different reasons, I might have chosen "complexity." The new appreciation of complexity that computers have made possible, both experimentally and theoretically, has brought with it a skepticism among many scientists toward fundamental laws (or models) that supposedly govern the universe (Maxwell's Equations, the Schroedinger Equation, the Standard Model) and are capable of explaining specific events. This antireductionist perspective inhabits the biological as well as the physical sciences and is apparent in the significance of epigenetics and the microbiome, whereby our very identity, both biological and psychological, is integrally bound up with the environment. With complexity have come new conceptions of emergence, pattern recognition, and intuition. Concerning "intuition," one need only think of the recent success of AlphaGo in defeating the GO champion Kim Se-dol. The machine does not operate by deducing solutions from any general principles of GO but, rather, by employing the neural nets of AI to learn what strategies are likely to succeed based on examining millions of games played by masters and by playing against itself. Similar learning technologies will soon inhabit self-driving cars and caretaking robots.

I would like to use this situation to reflect very briefly on the "postmodern condition"—but less as the loss of grand narratives, to which Van Lunteren alludes in his introduction, than as the decline of general laws and principles taken to underlie and to order our knowledge of the world. This is the postmodernity that Paul Forman damned in a widely read polemic against the practices of historians of technology, which turns on his view that a major cultural shift occurred around 1980 from the primacy of science (identified with general laws and disciplinarity) to the primacy of technology and to ends justifying means rather than the reverse.[4] I would say instead, while pushing the transition period back ten years, that with the primacy of the computer in both experimental and theoretical work, and serving as the dominant mediating machine in many areas of research, science itself has changed. Where unity and simplicity once ruled we now have complexity. And where deduction from general laws once constituted the ideal of a properly scientific explanation we now also have simulations, data mining, and AI, all dependent on the computer. Of course "the computer," as the mediating machine in all of this, can no more be subsumed under a single concept than can the balance or the engine. But the prominence of its many roles in both investigating and explaining the world suggests why Van Lunteren's big-picture history, organized around mediating machines, may be just what we need in the postmodern age.

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[4] Paul Forman, "The Primacy of Science in Modernity, of Technology in Postmodernity, and of Ideology in the History of Technology," *History and Technology*, 2007, 23:1–152.