Essay Review

History to reckon with

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Matthew Jones, *Reckoning with matter: Calculating machines, innovation, and thinking about thinking from Pascal to Babbage*. University of Chicago Press, Chicago, 2016, pp. 331, Price $34.00 hardback, ISBN-13: 978-0-226-41146-0; Jessica Riskin, *The Restless Clock: A history of the centuries-long argument over what makes living things tick*. University of Chicago Press, Chicago, 2016, pp. xiii, 548, Price $40.00 hardback. ISBN-13: 978-0-226-30292-8.

In 1673 G. W. Leibniz presented a machine to the Royal Society which was capable, in a mechanical manner, of performing multiplications. Robert Hooke observed the mechanism but was not especially impressed. He went away and made one of his own, showing it to the society to some applause shortly after, and then, apparently, forgetting about it. Given the retrospective importance attributed to calculating machines today as the forerunners of computers, this comes as a surprise. But Jones explains that to Hooke the calcuating machines was too complex an affair to be of interest. “It seemed to me,” said Hooke, “soe complicated with wheeles pinnions… springs screws stops and Truckles that I could not perceive it ever to be of any great use especially common use.” Leibniz’s machine was too cumbersome and so “could onely be fitt for great persons to purchase… and for great witts to understand and comprehend.” (Quoted in Jones, 2016, 65)

Matthew Jones shares with Hooke a keen awareness of the limitations of calculating machines. In a remarkable history of arithmetical engines from the seventeenth century to the present, he demonstrates that they were of extremely limited relevance to thinking about the nature of the mind. If modern science takes it as self-evident that thinking is something like computing, and that an artificial intelligence will one day (and perhaps already does) reason, then Jones’s book shows how the history of such assumptions is much shorter than normally supposed. Far from being models of reason, to people of the seventeenth and eighteenth centuries the calculating machines that preceded Charles Babbage’s Difference and Analytical Engines only mechanized narrow elements of thought – addition and multiplication – but were never imagined to be equivalent to the workings of the human mind. Minds are not machines, they supposed, but are lively, intuitive, active, and creative.

The liveliness of machines is also the subject of Jessica Riskin's *Restless Clock*, the title taken from G. W. Leibniz, who denied that living things were merely passive machines, along the lines of automata, but active, self-transforming machines, sentient and sensitive all the way down to infinity. According to Leibniz, if organisms are clockwork, then the clockwork is not dull and inert, but "restless" (Riskin, 2016, 6). Riskin, like Jones, offers a powerful criticism of modern science. For more than a century, scientists have rejected such lively views of matter and denied any agency for living things to transform themselves. Yet, Riskin shows, such a position had roots in the very forms of thought that modern scientists decry, and overlooks a rich vein of scientific thinking that the *Restless Clock* brings back to life.

Jones's *Reckoning with Matter* is a history of calculating machines, and the troubled efforts to produce them. It reveals what is at stake in building them, namely relations of natural philosophers, savants, and artisans. There have been numerous histories of scholars and artisans in recent years, ranging from Pamela Smith's *The Body of the Artisan* (Smith, 2004) to Pamela Long's studies of invention, authorship, and the arts (Long, 1991; Long, 2001; see also Bertucci, 2017; Roberts, Schaffer, and Dear, 2007; Werrett, 2010). Jones's book is a welcome addition to this literature, taking as its focus the nature of invention and how exactly hand and mind have been represented as integrated, or separated, in the past. Several historians have explored these relations through the history of automata, yet surprisingly that history has tended to overlook calculating machines (Schaffer, 1999; Riskin, 2007; Voskuhl, 2013). Jones shows them to have been equally evocative of lively debates over the material and intellectual elements of invention.

While Jones draws on the literature on science and artisans, he situates his argument above all in the history of technology, and proposes that historians of technology have tended to present technical change in one of two modes. They either adopt a collective, gradualist approach in which invention is a social process of innovation through imitation of existing technologies, downplaying the role of the individual, or they follow an heroic model centered on individual creative geniuses. Early moderns, Jones insists, did not make the divisions and dichotomies that such accounts presuppose, between imitation and originality, the social and the individual, design and production. These categories rather appear as the outcomes of historically-situated engagements between a variety of scholars, artisans, patrons, and audiences, whose status and identity were not predetermined prior to their interactions. Here Jones follows work by Lissa Roberts and others in recent years that has stressed the need to appreciate "mindful hands" or early modern practitioners who did not fit neatly into artisanal or scholarly identities but combined both craft and intellectual skills in their work (Roberts, Schaffer, and Dear, 2007).

At the same time, Jones argues, the period between c. 1600 and 1850 did witness the gradual bifurcation of these categories, and it is this process which interests Jones and which the history of calculating machines neatly exposes. Hence *Reckoning with Matter* offers a "genealogy of the gulf between theory and practice later to be reified by the new categories of science and technology" (Jones, 2016, 9). Rather than simply see this as a simple trip from "mindful hands" to minds versus hands, Jones unveils a dynamic multiplicity of positions, in which divisions emerged but usually in an awkward dependency between practitioners vying to be scholars or artisans or both. Ultimately, the period witnessed the emergence of a powerful discourse of “hylomorphism”, a term Jones takes from Tim Ingold, in which design ideas are imagined to exist apart from and prior to the process of realizing them in a physical production (Jones, 2016, 9). Put another way, many scholarly representations of artisanry shifted between what David Pye calls a “craftsmanship of risk”, implying a combination of artful skill and creative improvization, and a “craftsmanship of certainty”, equating art with the mere execution of someone else’s ideas (Jones, 2016, 14). Modern understandings of e.g. patent law and intellectual property then rest on hidden assumptions of this hylomorphic division, which Jones does a brilliant job of making visible.

Chapter One of *Reckoning with Matter* introduces calculating machines constructed in the seventeenth century by Blaise Pascal and Samuel Morland, using ingenious mechanisms to carry tens and enable addition and multiplication in a compact, and usually aesthetically impressive, machine. The second chapter considers Leibniz and Robert Hooke’s solutions to mechanizing reckoning, while chapter three considers how the labours of these protagonists were engaged with emerging cultures of intellectual property and protection. Chapter four is a fascinating account of "emulation", an early modern concept that entailed the imitation of an invention with a view to improving it, often invoked as a way to legitimize copying someone else by saying a “new” invention was more than just a copy. Jones makes a convincing case that emulation was highly productive of innovation in the eighteenth-century economy and makes evident that copying and innovation cannot be easily separated or contrasted in this period. Chapter five examines Charles Stanhope’s attempt to build a calculating machine in the 1770s, and the interplay of theory and practice, ideas and their realization in the process of invention. Highlighting Stanhope's insistence that good ideas must be combined with their practical realization, Jones demonstrates how enlightened improvement had to rely on such combinations and, contra Joel Mokyr's ideas about "industrial enlightenment", not by the circulation of knowledge alone.

The final chapter provides a remarkable examination of early modern debates over imitation and originality in the arts and sciences and how they anticipate and shed light on more recent debates over the nature of computers and machines as capable of originality and creativity, and the adequacy of comparing them to the mind. Against Ada Lovelace's view that no calculating machine could be original, because it only ever followed procedures to combine elements in a variety of ways, Alan Turing insisted that computers could generate features that appeared original via exacly this process. Combinatorial acts could appear novel and creative, because this is what invention ultimately consists of. Against a growing rejection of 'emulation' in favor of an equation of imitation with merely mechanical copying, Jones tells a fascinating story of the relation of the calculating machine to early modern notions of mind – or rather, a lack of relations, because as he points out, it was extremely rare to make any such connection. This is because in the eighteenth century, thinking and reasoning were not equated with calculation, but involved much more. Even mathematics was irreducible to any logical manipulation of signs but must involve insight, intuition and creativity, otherwise it might seem merely mechanical and require no special genius. To say with G. C. Lichtenberg that Leonhard Euler was the "greatest calculator" was, as Jones says, "damning praise" (Jones, 2016, 218). Only in the nineteenth century, once reasoning was more commonly allied to reckoning, did it make sense to ask if minds were calculating machines of a higher order, or if computing machines might be capable of thinking in a meaningful sense.

Throughout, Jones's explanations of the workings of the machines are a picture of clarity, and focused enough to reveal important minutiae without getting lost in detail. Two problems any calculating machines face, for instance, are what Jones calls the problem of "sufficient force" – how do you provide enough force to turn all the cogs in the machines – and the problem of "keeping it digital" - how do you make everything move discretely so wheels don't jam up if they get stuck in between neat integers. Appreciating these then makes sense of centuries of laborious and ingenious handiwork to overcome them. Hooke had the advantage of seeing Leibniz's solutions to these problems. But most inventors did not.

One wonders if Hooke appreciated Leibniz's peculiar understanding of "restless" machines when he inspected the latter's calculating engine at the Royal Society in 1671. This understanding is inspiration for Riskin's *Restless Clock*, a book about "active" versus "passive" mechanism. We tend to think of mechanism as implying an inert, passive nature, to which agency cannot be attributed, and this is seen in the sciences as an antidote to the supposed mysticism and obscurity embodied in explanations that invoke God or a principle of vitality to explain life. Despite scientists' aversion to such agential attributions, and their identification of this trait as anti-mystical, it originated, Riskin points out, in an attempt to bolster the power of God. Fearful of Catholic and popular attributions of spirit to superstitious deities and earthly things ranging from bread and wine to witches and charms, seventeenth-century natural philosophers denied the agency of matter, describing instead a clockwork universe set running and maintained by divine agency alone. Hence the irony that modern science's insistent distrust of natural agency emerged from, and owes its existence to, a religious motivation and theology. Indeed, Riskin identifies it as a "science-theology" to make the point of connection (Riskin, 2016, 79). Not only is this way of talking rooted in religion, but it is also an ill fit to what scientists actually do. As Riskin notes, it remains common to attribute agency in the form of analogies and metaphors to natural things, so that e.g. genes have "strategies" or "agendas": as long as agential words are cast in inverted commas, they are safe, implying nature does *not* have such things! This metaphorical mode is the symptom of an historical malaise that Riskin sets out to document, if not to cure. History she argues, reveals the origins and contours of changing views of agency in nature, and in particular expands and enriches the available options. Then, in a *tour de force* voyage through the sciences from the seventeenth century to the present, Riskin traces the history of savants and philosophers who did not opt to promote a view of nature as a merely passive mechanism brought to life by God, and explains how "science-theology" ended up as just "science" today.

Riskin grounds her argument by establishing a series of contexts in which an assortment of artisans, engineers, savants and science fiction writers created lively machines that provoked thought about the material nature of life and mind. Chapter one explores the renaissance automata of churches and princely gardens that inspired figures such as Descartes to propose that man might be a machine. Riskin insists in chapter two that the Cartesian idea of mechanism was much more restless and active than has been previously appreciated. Further chapters evoke the automata of various ages, and while many of these are familiar – Vaucanson's defecating duck, Karel Capek's robots, or Grey Walter's tortoises

– Riskin reveals other less well-known artifacts (Reisel's artificial man and Eric the Robot are particularly impressive). Against this backdrop, Riskin charts the ideas of a series of thinkers and scientists who argued for and against agency in nature, among them Leibniz, La Mettrie, Diderot, Kant, Lamarck, Darwin, and Weissmann. As seventeenth-century philosophers were forging a natural theology giving God a monopoly on agency in the natural world, figures such as G. W. Leibniz offered an alternative. The universe was no inanimate clockwork, as Leibniz insisted, but filled with lively, sentient and self-transforming matter.

The rejection of "brute mechanism" continued in the work of enlightened materialists such as La Mettrie, and in the first fully-fledged evolutionary theory of Lamarck. Riskin insists that modern science has misunderstood Lamarck. Instead of identifying his ideas of the inheritance of acquired characteristics as pseuod-scientific mysticism, they should be recognized as a radical rejection of spirit in the age of the French Revolution. Arguing for a "vital, mechanical striving" in nature was theologically dangerous, because it denied God's agency in the world, and left it to nature, exactly what neo-Darwinians like Dawkins would want to promote. Lamarck also made history central to biology, since evolution could only be understood through the contingencies of a multitude of environments and situations through which organisms lived. The second half of the book then traces the demise of Lamarck, and the place of God and history in science, as biology (the term coined by Lamarck) was institutionalized in newly-configured research universities in the nineteenth century. Here the sciences were divided sharply from theology, tearing apart passive mechanism from divine agency. Even though Darwin himself was much committed to Lamarckian ideas, a new mechanical and reversible theory of evolution emerged in this context as the "neo-Darwinism" of figures such as August Weissmann, banning any selftransformation or historicism from nature. Riskin concludes the book, after a foray into the role of cybernetics in these debates, with a remarkable critique of contemporary debates in evolutionary biology, cognitive science, and artificial intelligence. Figures such as Richard Dawkins, Steven Pinker and Daniel Dennett continue to resolutely promote passive mechanism despite its roots in early modern theology and the argument from design. In rejecting Lamarckianism and active mechanism they deny the relevance of history to science. But "history matters" concludes Riskin, revealing alternative paths to thinking about the nature of living things.

Both *Reckoning with Matter* and *The Restless Clock* challenge contemporary assumptions about science and technology using history and this is surely to be applauded, though as a result both books are less explicitly engaged with historiography and the work of other historians of science than might be the case. The cast of characters is thus, to some extent, rather familiar – the "great witts" of western thought are salient, though we do learn of a diverse range of less well-known artisans and automaton-builders. Across both books, however, there are only a handful of references to women. One wonders how women figure in the history of calculating machines, as inventors of machines and as practitioners of calculation. Marie Hicks has written recently of the "programmed inequality" and exclusion of women from the computing industry in post-war Britain and the detriment to innovation this resulted in (Hicks, 2017). What might be said of an earlier period? Was invention an exclusively male domain, or did women see themselves as inventors, and how did the gendering of invention change over time? Some calculating machines have been attributed to women inventors in the nineteenth and twentieth centuries and it would be interesting to know more about their stories (Stanley, 1995, 436). Historians increasingly highlight the role of women and the family in early modern scientific enterprises, and the history of instruments might usefully be considered in relation to this work (e.g. Leong, 2013; Rankin, 2013; DiMeo and Pennell, 2013). Amy Froide has indicated that early modern women were much more skilled in arithmetic and accounting than has been previously recognized, and while accounting was a "masculine art" much female labour was spent on it (Froide, 2015). Robert Hooke noted that calculating machines were too complicated to be of "common use", and one wonders if wives and daughters consituted one of the alternatives, enlisted to keep accounts by their fathers and husbands? Certainly many women laboured as "human calculators" in astronomy, navigation, and other technical arenas from the eighteenth century (Grier, 2005). It is notable then that calculating machines began to take on a different significance from the time of Babbage and Lovelace, when the idea that reasoning was calculating became more commonplace. Could this have been a corrollary of the shift of science from the early modern home, where men and women shared experimental (and inventive?) inquiries, to more independent male spaces of study in the nineteenth century, such as the university laboratory or museum? Did these changes impact on the rejection of women as inventors and calculators in the following century?

Hooke also rejected calculating machines because they were hard to use and repair, "the multitude of parts must make it exeeding hard to put into good order, and extraordinary apt to be put out of it." (Birch, 1757, 87). Such a consideration was also reminiscent of the domestic context of experimental philosophy in Hooke's time. Early modern householders, men and women, valued goods that were useful, endured over generations, and were easily repaired. Hooke later promoted another of his inventions, a depth sounder, on the basis that it was easily maintained, "any one, almost, shall be able to make, or to mend it"

(Hooke, 1726, 235). One imagines that the home, and such views, needed to change significantly before calculating machines could be widely valued as something more than princely curiosities and their capacities given authority as models of the mind.

It would be interesting to explore the social context of calculating machines further, but of course there is only so much that can be covered in works on the *longue durée*. Indeed, another remarkable feature of these books is their temporal scope, passing from the early modern period to the present, and demonstrating the relevance of the former to the latter. Both books are simultaneously focused case studies and broadly relevant essays, revealing of particulars and generally applicable. Evidently the days when historians of science agonized over the field becoming lost in a plethora of overly-detailed case studies are over. Both volumes bring out the fine technical details of calculating machines and agential metaphysics, and then situate them in much longer-term trends and developments. These have a direct bearing on present-day debates at the heart of science and technology. Both books disrupt comfortable continuities that underwrite influential technoscientific narratives today. It's just not enough to adopt an anti-agential position in the present once you accept the theological roots of such an argument. It's just too simplistic to insist on divisions of mindful invention and dull execution in systems of intellectual property. Making the mind a reasoning machine just doesn't fly: it only works if you think in a peculiar way about minds that is a recent trend and by no means obvious. The success of history of science surely resides in its capacity to offer powerful correctives, rooted in careful historical scholarship, to studies in the humanties and sciences that too often takes on face value histories of science, technology, philosophy and economics that fail to interrogate modern assumptions and truisms about these enteprises. One wonders if the scientific community might take on board these historical lessons. Perhaps the time has come for historians of science to become scientists in their own right: instead of waiting for others to develop theories and approaches that take history seriously, maybe we should just get on and do it ourselves. In any case, the history of science, in these two books, is something to be reckoned with.

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