Katharine Park and Lorraine Daston, eds. *The Cambridge History of Science*.

Volume 3, *Early Modern Science*. Cambridge: Cambridge University Press, 2006. xxvi + 866 pp. index. illus. tbls. $160. ISBN: 0–521–57244–4.

Lurking below the surface of *Early Modern Science* is the question of how to deal with the Scientific Revolution in light of the enormous number of recent studies that have breached the boundaries of the grand narrative of paradigm shifts and sea changes in the content and methodology of natural studies. Park and Daston are acutely aware of this question and solicited a volume of contributions that "has challenged the traditional view of the 'Scientific Revolution' while emphasizing profound but diverse changes in natural knowledge" (i) that occurred in Europe from 1490 to 1730. This strategy embraces the complex message that the contributors collectively voice: that the old narrative is abandoned with difficulty, that it no longer fits the historical record and must go, and that we all miss it very much and need a replacement. But creating that replacement is no easy task in a field endowed with a diversity of scholarly perspectives, which has produced histories that are in some instances difficult to reconcile and which itself has drifted away from history of philosophy and toward a broader cultural study. The result is a mosaic of overlapping studies retelling elements of the Scientific Revolution, and yet indicating where this retelling fails, while providing a rich critical apparatus of expansive, meticulous footnotes that document recent scholarship.

The diversity of historiographical perspectives is superficially evident in the structuring of *Early Modern Science* into sections of philosophical histories, studies of the people and sites producing new knowledge, disciplinary histories, and essays on how changes in natural knowledge were contextualized in other aspects of culture: for example, art, religion, and literature. Contributions in the first category present the traditional face of the Scientific Revolution, emphasizing transformations in epistemology and new ontological models of nature.

After the editors' excellent historiographical introduction, Dan Garber develops the "metaphysical foundations" approach familiar to historians of science, emphasizing the mechanization of the world picture and the roles of mechanical philosophy, mathematization, and quantification in revolutionizing science. Framed in terms of the bankruptcy of Scholastic-Aristotelian natural philosophy, Garber's account features the emergence of mathematical realism and abstraction by Johannes Kepler and Galileo Galilei, the rejection of Aristotelian matter theory and metaphysics by sixteenth-century chemical philosophy, and, ultimately, its replacement by Robert Boyle's mechanical corpuscular philosophy, which was built on the twin foundations of Cartesian materialism and Pierre Gassendi's adaption of classical atomism. Culminating the Scientific Revolution is the new philosophy of Isaac Newton and Gottfried Leibniz, after which the search for a consensual metaphysical basis for experimental science was effectively separated from "the scientific enterprise itself" (68).

Lynn Joy then nuances this traditional view of a rigid medieval Aristotelian paradigm and examines how the Philosopher's ideas were adapted to new problems and yielded with reluctance to the new science, which is marked by Boyle's rejection of substantial forms as "intrinsic causes of natural substances" (78), signaling the breakdown of any meaningful distinction between internal and external efficiencies. In due course, Newton also rejected Aristotelian causation, but retained a dualism of passive and active principles in matter. Joy briefly acknowledges the importance of alchemical theory to Newton, but does not enter into discussion of it, instead presenting Newton as a bridge between sixteenth-century neo-Aristotelian thought and corpuscular philosophy, sustaining the basic story of the Scientific Revolution articulated by Garber. But it is precisely to the history of alchemy (and medicine) one must look for antecedents to both corpuscular philosophy and experimental science.

Recent work in these areas reveals the limitations of Garber's account and shows that the traditional story of the triumph of inert mechanism over inner efficient causes does not accurately describe seventeenth-century natural philosophies, in which hard bits of matter, vital spirits, and efficient agencies often intermingled. Boyle and Newton drew on a well-developed experimental tradition and corpuscular matter theory derived from thirteenth-century Aristotelian alchemy and fused with Paracelsian spagyrical methods: it was seventeenth-century alchemy and iatrochemistry that provided them with the materialist theoretical basis and quantitative experimental methods on which to develop a replacement for Aristotle's substantial forms, not the Cartesian clockwork mechanism and Gassendian atomism.

Another traditional hallmark of the transformation of medieval natural philosophy into early modern science is the development of experimental methods and changes in philosophy required to validate the results of artificial experiments. Peter Dear examines new meanings attached to *experiment* that gave factual authority to individual observations by reliable witnesses. The key problem was how to reconceptualize Aristotle's scientific method, which prioritized sensory experience in constructing universal and demonstrable knowledge but disregarded anomalous individuals, in order to empower particular results of contrived, individual set experiments, such as Galileo's inclined plane demonstrations of accelerated motion. To legitimize the experimental method, seventeenth-century scientists stressed repeated observation: indeed, the ability to replicate results of set experiments at any time. Galileo referred to repeated observations, but there remained the philosophical problem of how to use these set experiments to legitimize something like epistemic knowledge. Newton argued in the famous query 31 of his *Opticks* the validity of a method of analysis based on inductive inferences from a single, well-conceived experiment in the absence of convincing counterevidence, an idea that Dear argues came from mixed mathematics rather than Baconian induction.

But William Harvey also repeated experiments and encouraged his readers to repeat his and see for themselves, which they did. Harvey's epistemology was based on Galenic *autopsia*, the pedagogical principle that one should witness for oneself, which was revived by sixteenth-century medical humanists. Dear claims that these sorts of observations were not regarded as yielding natural knowledge because they were artificial, and that Harvey and other anatomists understood Aristotle's claim that vivisection could not yield natural knowledge. Again, we can look to the history of chemistry for insight: medieval alchemists argued the legitimacy of art with respect to natural knowledge, claiming that their laboratory methods did not violate nature, but rather replicated nature's own methods to achieve natural ends. Medieval alchemists, like the medieval physicians, regarded themselves as nature's ministers, not violators, explaining why alchemists asserted the legitimacy of their laboratory insights into nature and why anatomists from the early fourteenth century to Harvey's day vivisected animals for the sake of scientific demonstration. Thus, while scrutiny of mathematical sciences and physics might suggest the problematic nature of individual experiment in the early seventeenth century, alchemists and physicians were already quite at home with empirical reality. Physicians regularly confronted both theory and practice in their quotidian attendance on the sick, and individual observations were given authority in medical *consilia*.

If the nature and overarching significance of scientific change in this period remains in dispute, that there was an intensification of scientific inquiry, fed by external factors such as exploration, capitalization, and new technologies — and that all this produced a wealth of new information that nourished interlocking social, political, and economic changes — is well-established in these studies. It is a clear strength of this volume that early modern science — once construed to center on epistemology, physics, cosmology, and mathematics — now embraces medicine, natural history, alchemy, astrology, and sociological and cultural-historical approaches aimed at contextualizing intellectual change in other cultural activities. Individually the contributions to this volume are thoughtful, well-researched summations of the state of the art in their specific topical areas. As such they constitute a useful disciplinary resource for teachers, but also mark the way for the next generation of extensions, revisions, and syntheses.

JOLE SHACKELFORD
University of Minnesota