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A. Rupert Hall. *The Scientific Revolution, 1500-1800: The Formation of the Modern Scientific Attitude.* Boston: Beacon Press, 1966. xviii + 390 pp. Out of Print (paper), ISBN 978-0-582-49133-5.

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A. Rupert Hall and the Scientific Revolution

Note : This review is part of the H-Ideas Retrospective Reviews series. This series reviews books published during the twentieth century which have been deemed to be among the most important contributions to the field of intellectual history.

The Scientific Revolution of the seventeenth century was a creation of the middle third of the twentieth, and its historiographical career has mirrored that of the myriad ideas and institutions born at that time: first rising to wide acceptance, then fragmenting under critical attack, now persisting in changed form.[1] The term "The Scientific Revolution" was coined by Alexandre Koyre in the 1930s and popularized in 1949 by Herbert Butterfield, who famously proclaimed that it "outshines everything since the rise of Christianity and reduces the Renaissance and Reformation to the rank of mere episodes, mere internal displacements, within the system of medieval Christendom."[2] For two generations of college (and graduate) students, however, the Scientific Revolution was defined not by Koyre or Butterfield but by A. Rupert Hall's book, *The Scientific Revolution, 1500-1800: The Formation of the Modern Scientific Attitude.* Indeed, it is no great exaggeration to say that The Scientific Revolution was the subject, and *The Scientific Revolution* the text around which the new field of the history of science first coalesced. It was the first great exemplar of the belief that science was a valid subject for historical inquiry – a belief whose offspring Hall did not anticipate nor entirely welcome.[3]

The focus of Hall's book is well described by its subtitle: "the formation of the modern scientific attitude." To Hall, it is the emergence of a new attitude, a new world view, that is the essence of the Scientific Revolution, not the development of any specific theory (though these were necessary to "vindicate" this attitude through their success). This new attitude was modern; indeed, it was the essence of modernity. It also was scientific; in fact, it was the origin of what we truly can call science and the source of its peculiar power. Thus Hall, like Butterfield before him, placed science at the center of modern Western culture and pointed to the Scientific Revolution as the great moment of change, the point at which

both science and the West broke free from medieval stasis and began their steady upward climb.

The basic principles of this new attitude were that "the only sort of explanation science could give must be in terms of descriptions of processes, mechanisms, interconnections of parts," and that "the only realities were matter and motion" (p. xvii). These principles stood in sharp contrast to the medieval world view, inherited from Aristotle, which explained things in organic, teleological, and animistic terms. Equally important, adherents of the "new philosophy" married theoretical abstraction to rigorous empirical observation, unlike their forebears who had seen philosophical inquiry and empirical practice as unrelated endeavors.

Hall begins his account with a description of science in 1500, emphasizing both the power of the Aristotelian system and the slow emergence of challenges to it, such as impetus theory. Such challenges were limited in scope and ambition, and they remained so throughout the sixteenth century: in Hall's view neither Copernicus nor Vesalius was a revolutionary, though their ideas and discoveries later inspired others who were. Nevertheless, despite the narrow focus and uncoordinated nature of these challenges, Aristotle's cosmos had begun to decay. Although late medieval scholars could train themselves to think like the Greeks of antiquity, they in fact were not. As a result, by 1600 the greatest bulwark of Aristotelian thought was mere mental inertia, which was itself a weakening force, as tradition sat ever more lightly upon the shoulders of natural philosophers.

After setting the stage for rebellion, Hall begins his narrative proper by exploring the intertwined stories of the two most fundamental attacks on tradition: the new mechanics and the new astronomy of the early seventeenth century. Here Hall is at his best, for he is able to make clear why these specialized attacks brought down the whole cosmos. As Hall writes, "Aristotle's cosmos was a unity in conception, a true system of thought. Consequently, ...the whole authority of the magnificent interlocking system of thought bore down upon an assault at any one point. How could a mere mathematician assert the earth's motion when a moving earth was absolutely incompatible, not only with sound astronomical doctrine, but with the whole established body of natural philosophy? Logically, to doubt Aristotle on one issue was to doubt him on all, and consequently some problems of the scientific revolution, which may now seem to involve no more than the substitution of one kind of explanation for another, were pregnant with consequence since they implied the annihilation of extant learning" (p. 35).

In Aristotle's cosmos, the causes of motion and the arrangement of the universe were inextricably intertwined. Objects moved in accordance with their inherent natures, and the nature of terrestrial things was wholly distinct from that of celestial bodies. To bridge that gap was to render both the heavens and the earth unintelligible. As Hall explains, the Copernican hypothesis, as a calculating device, did no harm to this structure. As a physical hypothesis, however, it required a wholly new understanding of all matter and all motion. Galileo's great triumph was to recognize this fact and to create, almost de novo, the new science of mechanics it required. In this new science matter was defined by abstract yet measurable "primary" qualities (mass, extension) and motion was described in terms of speed, force, and inertia. Thus, although Galileo did not complete the revolution in mechanics he began (that, and the creation of a compatible celestial mechanics, was left to Newton), mechanics is clearly the hinge upon which the Scientific Revolution turns. As Hall writes, "it is no exaggeration to describe [Galileo's mechanics], with all the new structure of thought of which it was the crowning achievement, as the justification of the new philosophy, as the beginnings of exact science which consciously set itself to proceed by other ways than those of the past, and which hardly doubted that all the past philosophy of nature was vain" (p. 91).

After telling the story of the astronomical-mechanical revolution, whose theme is the union of abstraction and empirical observation through mathematical analysis, Hall then proceeds to tell the story of experimentation, the other high road to union. Here he begins with Harvey and Bacon, the first ones who, in his view, truly understood experimentation to be an organized method of inquiry rather than a method of demonstration. From there he moves on to discuss the emergence of scientific societies, notable for their interest in experimentation, and to explore the role in the scientific revolution of new sources of empirical evidence, such as practical craft knowledge, and new instruments, such as the telescope and microscope. As a rule, Hall views interest in experimentation and empirical observation as consequences rather than causes of the Scientific Revolution, but in their birth he sees foreshadowed the "large institutes, freely endowed" and the "great plants required to produce antibiotics and radio-active isotopes" of twentieth century science (p. 243).

In Hall's account, Newton is the culmination of both

the mathematical and the experimental approaches to wedding abstraction to observation. He is the great synthesizer, the one in whom all the emerging qualities of rational science meet and merge. As he writes, "It is no detraction from Newton's originality to point out that all his discoveries were firmly rooted in science of the time–that like a helmsman he was borne along by the stream . . . Newton, in fact, won such immediate esteem because he saw clearly the things to which others were groping, because he was so fully in harmony with his age" (p.246). As a result, Newton appears as a conqueror rather than a rebel; if Galileo is the Scientific Revolution's Tom Paine, Newton is Jefferson and Washington rolled into one, both the author of the new constitution and the first ruler of the new "principate" of science.

Hall continues his narrative through the emergence of "rational" chemistry, biology, and electrical science during the eighteenth century. The chapters in which these developments are chronicled, however, have the feel of filler, there to get the reader from the excitement of science's birth to the majesty of its enthronement in the nineteenth century. (Eighteenth century science has remained a somewhat neglected field, outside of studies of Lavoisier and the chemical revolution, though it has proven fertile ground for studies of the "cultural meaning of the scientific revolution." [3]

Hall is at his best when describing the changes in worldview that accompanied the fall of Aristotle and the rise of the mechanical philosophy. He is weakest when he attempts to provide explanations for the transformation he characterizes so vividly. In fact, he spends remarkably little time discussing the possible causes of the Scientific Revolution, devoting little more than a page in the introduction and one in the conclusion to the question. Combining these two passages, one finds that decline of Aristotle was "in part brought about by the rival Christian authority," since "no Christian could ultimately escape the implications of the fact that Aristotle's cosmos knew no Jehovah" (p. xvi). At the same time, the new notions of seventeenth century science "partly arose out of the critical inquiries of the thirteenth and fourteenth century philosophers, partly they were learned from ancient authors read with new eyes, [and] perhaps most of all they were produced by the intellectual frustration caused by the stagnation of late medieval science" (p. 372).

These arguments are incomplete and unpersuasive as presented, however. Christians had managed to "escape" the implications of Aristotle's cosmology for centuries–why could they do so no longer in 1600? Similarly, why did Galileo and his allies see traditional science as stagnant when many of their contemporaries did not? Other, related weaknesses also can be found in Hall's account, all stemming from the absence of the world beyond the library and the laboratory and from his almost exclusive focus on the fields that adopted the new philosophy most completely and on the aspects of the new philosophy that appear most rational to modern eyes. As a result, the reader of *The Scientific Revolution* finds almost no mention of the dramatic religious and political upheavals of the sixteenth and seventeenth centuries, nor does he/she encounter any references (beyond the disparaging) to Plato, neo-Platonism, or the powerful "Hermetic" strain in early modern science.

Despite these limitations, *The Scientific Revolution* was a widely read and influential book during the 50s, 60s, and 70s and is still a common introduction to the topic. Perhaps what made Hall's book so popular and persuasive in its heyday was the optimistic faith that animated it. To Hall, the world could be understood and mastered by reason, if reason were disciplined by experience and freed from dogma as it is in modern science. Reason so disciplined would lead to both material and social progress, as evidenced by the rise of the democratic, technically sophisticated West. This set of beliefs–what one might call a "broad church" form of positivism–was widely shared by the leading postwar interpreters of science to the public, and it resonated with a society that was fascinated by (and fearful of) the power of science-based technology to transform the world. [4]

A later generation of historians of science, however, has subjected Hall's account of the Scientific Revolution to sharp criticism. Although they are Hall's heirs in their commitment to the historical analysis of science, they did not inherit his optimistic faith in science nor his understanding of its place in Western culture. Indeed, all three of the words "The," "Scientific," and "Revolution" are now disputed terms, to say nothing of reason, progress, and the Rise of the West. [5] One prominent historian of seventeenth century science even begins his survey of the Scientific Revolution by stating that "There was no such thing as the Scientific Revolution . . . ." [6]

Yet, when one compares Hall's account of the Scientific Revolution to more recent accounts, one is struck as much by the continuities as by the contrasts between them. At a certain basic, descriptive level, Hall's core narrative still provides the essential framework upon which other accounts build or to which they respond. The historian who wrote "there was no such thing as the Scien-

tific Revolution," finishes that sentence by writing "and this is a book about it." [7] More importantly, the "it" he and other recent historians describe still covers the same basic cast of characters, rarely straying beyond Hall's top ten: Vesalius, Copernicus, Brahe, Kepler, Galileo, Bacon, Harvey, Descartes, Boyle, and Newton. In addition, "it" occurs during the same crucial time period–the seventeenth century, especially the period from Galileo's Starry Messenger to Newton's Principia–and "it" is defined by the same essential transformation: the overthrow of Aristotle's teleological, animistic cosmos and its replacement by a mechanistic "new philosophy." Even more, both Hall and his later critics agree that this seventeenth century revolution in science involved a change in world-view and that it, therefore, is not explicable in terms of new facts that forced conversion.

This basic descriptive framework, however, now supports a new interpretive structure. The novel aspects of this new structure derive from three key changes in how historians of science understand science and history. First, the scope of historical inquiry has expanded to encompass all systematic attempts to understand the natural world, not just the ones that most resemble or that led most directly to modern physical science. Thus, Kepler's neo-Platonic number mysticism and Newton's alchemy are no longer chaff to be sifted from the wheat of rational science but constitutive elements of their thought. Similarly, natural history, cartography, and other "Baconian" sciences are no longer the awkward younger siblings of the classical physical sciences but distinct enterprises with their own histories. Indeed, perhaps the most important result of this expansion of the scope of inquiry has been an increasing awareness of the variations in knowledge and practice from field to field and place to place. Knowledge increasingly is seen as a local product, and the history of science is increasingly the study of the varieties of natural knowledge.

Second, the bounds between science and the rest of culture have been dissolved. To the new generation of historians of science–best described as "constructivist" because of their emphasis upon each actor's active role in the construction and reconstruction of his/her world of experience–science is conceived of as a cultural product to be studied like any other cultural product. In practice, this principle has encouraged historians of science to understand their goals increasingly in synchronic rather than diachronic terms: the historian's mission is to locate ideas, actors, and practices in their specific social-historical contexts rather than to trace their genealogies. Thus, Galileo's new science was an attempt to win a place for the mathematician in the Medici court, not an episode in a centuries-long dialogue about impetus and local motion; Boyle's experimental philosophy was a response to the social chaos of the English Revolution, not the ancient problem of the plenum and the void. [8]

Third, constructivist historians of science are interested in the production and legitimation of knowledge, and they do not accept simple "truth to nature" as an acceptable explanation of either. If knowledge is power, power is constitutive of knowledge, an idea wholly foreign to Hall. To him, power could promote or conceal truth, never define it. Much medieval science was "simply wrong, both in fact and in interpretation," (p. xiii) and correct understandings were bound to win out, once discovered.

These three changes have combined to produce a new understanding of the Scientific Revolution: (following Steven Shapin) the Scientific Revolution is now seen as a varied set of responses to the crisis of authority, both political and philosophical, in late sixteenth and seventeenth century Europe. As such, it plays a different, much less central role in the creation of the modern world than it did for Hall. To Hall, "Compared with modern science, capitalism, the nation-state, art and literature, Christianity and democracy, seem regional idiosyncrasies, whose past is full of vicissitudes and whose future is full of dark uncertainty" (p. 367). To his constructivist heirs, however, the rise of science is more the explanandum than the explanans, having ceded its place to the "regional idiosyncrasies" Hall put to the side.

Constructivist history of science has many virtues, but there is one aspect of it that troubles some practitioners: in many constructivist accounts, the natural world imposes remarkably few constraints upon human actors. Instead, the social world provides (almost) all the valuable resources and imposes (almost) all the meaningful constraints for the struggles among its inhabitants. If carried too far, such an approach may produce the very anachronism it seeks to avoid by transposing our present confident complacency regarding the control of nature to a time when "man's Empire over Nature" had yet to be won. Perhaps in recognition of this tendency, some of the most interesting recent work in the field explores the origins of new attitudes towards nature and its control, looking beyond the laboratory to the craftsman's shop, the preacher's pulpit, and the collector's cabinet of curiosities. [9] Here Hall's classic narrative may prove valuable once again, helping us to understand the relationship between the "new philosophy" and the new call

to mastery sounded by the heralds of modern science.

Notes

[1]. For a very thorough exploration of the history of the idea of the scientific revolution, see H. Floris Cohen, *The Scientific Revolution: a historiographical inquiry*, (Chicago: University of Chicago Press, 1994).

[2]. Three of Koyre's key essays of the 1930s, in which he defined the concept, were published together as Etudes Galileennes, (Paris: Hermann, 1939-40). The Butterfield quote is from p. 7 of his *The Origins of Modern Science, 1300-1800*, revised ed. (NY: the Free Press, 1957, first edition 1949).

[3]. There had been many histories of science written before Hall, but, with the exception of Butterfield, they had been written by philosophers and scientists. Some, like Koyre, were excellent historians, but their basic questions were philosophical rather than historical in nature.

[4]. Margaret Jacob, *The Cultural Meaning of the Scientific Revolution*, (Philadelphia: Temple University Press, 1988).

[5]. Two leading examples of such interpreters of science to the public are James Conant and Jacob Bronowski. See Conant, *Modern Science and Modern Man*, (NY: Columbia University Press, 1952), and Bronowski, *Science and Human Values*, (London: Hutchinson, 1961).

[6]. "The" because it implies that the Scientific Revolution of the seventeenth century was unique, unlike other episodes of change in science; "Scientific" because science is an anachronistic term-natural philosophy is more accurate; and "Revolution" because the extent, pace, and timing of the changes in science during this period-as well as the periodization itself-are under debate: can anything that lasts 300 years and still only affects the ideas of a small elite be called a "revolution"?

[7]. Steven Shapin, *The Scientific Revolution*, (Chicago: University of Chicago Press, 1996), p. 1.

[8]. See Mario Biagioli, *Galileo, Courtier: the practice of science in the culture of absolutism*, (Chicago: University of Chicago Press, 1993) and Steven Shapin and Simon Schaffer, *Leviathan and the Air Pump: Hobbes, Boyle, and the experimental life*, (Princeton: Princeton University Press, 1985).

[9]. See, for example, Paula Findlen, *Possessing Nature: museums, collecting, and scientific culture in early modern Italy*, (Berkeley: University of California Press, 1994).

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