The Mechanization of Natural Philosophy

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The Mechanization of Natural Philosophy

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Preface

This book is the quite distant result of a workshop entitled "The Mechanization of Natural Philosophy," held at the Maison des Sciences de l'Homme-Alpes (Grenoble), November 17–19, 2005. The workshop was part of a program on the general theme "From Natural Philosophy to Science," generously sponsored by the European Science Foundation; additional subsidies were given by the Université Grenoble II, Ville de Grenoble, Métro, and Ministère des Affaires Étrangères. With the exception of the essay by Gideon Manning, who kindly agreed to contribute to the volume without having been present in Grenoble, all the papers here were read at the workshop in preliminary form and then thoroughly revised for publication.

In addition to the scholars whose essays follow in this volume, participants at the workshop also included Sylvia Berryman, Antonio Clericuzio, Egidio Festa, Alan Gabbey, Ofer Gal, Elzbieta Jung, Walter Roy Laird, Cees Leijenhorst, and Christiane Vilain. Their contributions to the workshop in Grenoble, whether through the presentation of a paper or through the participation to discussions, whether oral or written, whether mentioned in the footnotes or not, have left their mark throughout the arguments of this book. We hope that they all will be happy with the final result.

For her efficiency in helping to organize the Grenoble workshop, we thank Loredana Truong, administrator of the group "Philosophie, Langage et Cognition," Université Grenoble II. For their constant support from one workshop to the other, but also from one book to the next, we thank Hans Thijssen, Chairman of the European Science Foundation program "From Natural Philosophy to Science," and Cees Leijenhorst, the coordinator of the program.

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Introduction

Daniel Garber and Sophie Roux

Mechanical philosophy has been well-established as a historiographical category for some years now. However, recent historical research has revealed considerable complexity behind the often uncritical use of the term.

For a generation of historians, the mechanical philosophy was regarded as the principal alternative to Aristotelian orthodoxy in the period of the so-called Scientific Revolution. This has been shown to be a significant oversimplification of the situation, as historians of science have come to appreciate more and more the diversity of non- and anti-Aristotelian views available in the period. In addition to mechanical philosophies, in the period various alchemical, magical, and Platonistic philosophies were available, as well as alternatives to the dominant Aristotelianism that do not fit into any neat categories. Recent scholarship has also emphasized that even though the mechanical philosophy is closely linked to corpuscularianism, there existed alchemical and even Aristotelian corpuscularianisms that were not mechanical by any reasonable criterion. Though our focus in this volume is specifically on the mechanical philosophy, we certainly do not want to claim that it was the only alternative view on the table. But that said, many (though perhaps not all) important figures in the period did endorse some version of a mechanical philosophy. It is therefore important to investigate what exactly the mechanical philosophy may have been as well as the roles that it may have played in the intellectual life of the early-modern period.

The expression "mechanical philosophy" is burdened with multiple ambiguities. Because of its frequent use, it has sometimes slipped into becoming some kind of broad umbrella that may refer to at least four different enterprises: (1) the general program of substituting for the "common philosophy," i.e. the scholastic philosophy, a new philosophy, still to be identified; (2) the more specific rejection of Aristotelian hylemorphism and the correlated adoption of an ontology according to which all natural phenomena can be understood in terms of the matter and motion of the small corpuscles that make up the gross bodies of everyday experience alone; (3) the comparison of natural phenomena, most specifically the world and animals, to existing or imaginary machines; (4) lastly, the ontology associated with mechanics as a new mathematical science of motion, the laws of which are described as the laws of nature in general. Of course, these four enterprises were *sometimes*, in *some* places

and in *some* respects associated, but it should be clear that a natural philosopher engaged in the first enterprise does not necessarily have the same profile as a natural philosopher engaged in the fourth one.

However mechanical philosophy is defined, its ambition was greater than its real successes. Even if commentators still tell the triumphal story of the victory of mechanical philosophers over their Aristotelian counterparts, it is now admitted that the Scientific Revolution, if there was one, cannot be reduced to the rejection of Aristotelianism, the valorization of machines or the emergence of mechanics. In most of the natural sciences, explanations in terms of matter and motion alone failed to provide satisfactory accounts of phenomena, and turned out to be as circular or vacuous as their Aristotelian counterparts. The machines the mechanical philosophers proposed were not only imaginary, but most of the time had little to do with the machines actually constructed and used by mechanics or practitioners. Lastly, phenomena that could be subject to mathematical treatment seem to have been small islands scattered in a nature that appeared at this time fundamentally resistant to mathematization.

In the face of these complexities, one might consider simply abandoning the historiographical category of the mechanical philosophy. But to dispense with historiographical categories is not that easy; most of the time when we pretend to do so they keep lingering in the background. Moreover, it cannot be denied that by the end of the seventeenth century many natural philosophers did not speak any longer of substantial forms or occult qualities, that mechanisms and machines were systematically used by many as metaphors or models in the apprehension of natural phenomena, and that a new science of motion had emerged. Thus, our goal in this volume is not to argue for rejecting the historiographical category, but to problematize it and to explore its subtleties.

The inquiry is organized into three sections. First, how were our historiographical categories constructed? Second, how were the fundamental notions of mechanical philosophy, matter and motion, articulated in physics and in mathematics? Third, what kind of mechanization took place in domains usually considered as peripheral, such as meteorology, anatomy, medicine or chemistry?

Key questions are addressed in the first part of this volume, "The Construction of Historiographical Categories." In what respect is it useful for historians of scientific and philosophical ideas to qualify an author as a "mechanical philosopher," as a "Baconian" or as a "new philosopher"? How, when and why were such categories elaborated? Note moreover that over four centuries Aristotelianism not only endured many modifications, but it successfully confronted new problems. Thus, the question is not only the question of mechanical philosophers, but of their enemies, the Aristotelians. How did they react in the seventeenth century, when they were challenged by natural philosophers who explicitly claimed to be against the old philosophy of the School? Were there doctrines, arguments or intellectual practices that neither could accept? Through these questions, we hope to clarify the historical negotiations through which the opposition between "Aristotelian philosophy" and "mechanical philosophy," or between the "old philosophy" and the "new philosophy" were constructed.

At the very beginning of the book, Garber offers a general survey that may be seen as a preliminary warning. Recalling that the official "birth certificate" of mechanical philosophy is a celebrated passage of Boyle's *The Origin of Forms and Qualities According to the Corpuscular Philosophy* (1666), Garber wonders if the expression "mechanical philosophy" referred to anything at all before Boyle. Given that some of those usually considered as mechanical philosophers should not be treated as such (Francis Bacon, Galileo Galilei, Marin Mersenne), and the differences that exist among some others (René Descartes, Thomas Hobbes, Pierre Gassendi), Garber's thesis is that we should think of these pre-Boylean authors, and some others, as belonging to the pre-history of mechanical philosophy, rather than to its history proper: they did not see themselves as belonging to the same paradigm. Boyle's achievement would have been precisely to create, out of pre-existing elements, a new paradigm able to bring together different thinkers and to formulate a consistent program under which they could be united.

Giglioni backs up Garber's conclusion by examining a figure that is sometimes enlisted among the tutelary deities of mechanical philosophy and who is certainly presented as the spiritual father of the experimental philosophy practiced at the Royal Society, namely Francis Bacon. Though he does use words like *mechanicus* or "mechanical," when Bacon spoke of mechanical motions, it had little to do with the new science of mechanics. And indeed, he defended a metaphysics founded on material struggling and blind appetites that, notwithstanding current interpretations, underlies, for example, his description of the nature of heat. At this point, the question of the early reception of Bacon's works necessarily arises, in particular among the English natural philosophers who made his fame. Giglioni shows that there were actually different receptions, and that, except for Francis Glisson, they systematically set aside the metaphysics of appetites of the Lord Chancellor. In Samuel Hartlib's hands, Bacon was transformed into a religious utopian, but in John Webster's hands, into a Fluddian cabalist; Ralph Cudworth suspected him of atheism while Robert Boyle appreciated him for his methodological suggestions, and naturally for his praise of experiments. As for Boyle's reception of Bacon, while not the most faithful to his actual texts, it turned out to be the most productive at the Royal Society and beyond.

If Giglioni's essay is not sufficient to persuade the reader that *Wirkungsgeschichte* matters, she should turn to Roux's paper, which is devoted to the reception of Descartes' physics in the late seventeenth-century France. Roux starts with the fact that during the seventeenth century there were numerous different ways of opposing the new mechanical philosophy and the old Aristotelian philosophy. She argues, however, that, remarkably enough, Descartes eventually emerged as the benchmark by which the works of other natural philosophers of the seventeenth century fall either on the side of the old or the new. She consequently examines the French debate where this historiographical representation emerges, a debate that took place along with the development of a Cartesian propaganda in the 1660s and the ensuing official condemnations of the philosophy of Descartes. She shows quite systematically that the criticisms of Cartesian philosophers by the Oratorian Jean-Baptiste de La Grange, the bishop Pierre-Daniel Huet, and various Jesuits, Ignace Pardies,

Antoine Rochon, Louis Le Valois, Gabriel Daniel, René Rapin, and Honoré Fabri respond to the mockeries of Gérauld de Cordemoy, Jacques Rohault, Louis de La Forge, Bernard Lamy, Nicolas Malebranche or Antoine Arnauld concerning the scholastic entities. Not only does she contrast their philosophical arguments concerning entities and the norms to be respected in physics, but also their ways of defining the philosophical enterprise and its public.

Taken as a whole, the three essays demonstrate the importance of the late decades of the seventeenth century for understanding the emergence of the category of mechanical philosophy, the idea of Baconianism, the opposition of the ancients and the moderns. The late seventeenth century was not so much a period of invention as a period of stabilization, where the works of Descartes, Bacon, Galileo were received, commented on, interpreted. It is no small conquest of recent historiography to have shown the relevance, for the history of ideas, of periods of this kind and, in them, of *minores*. As we will now see, *minores* are part of the story in the second part of the book as well.

Mechanical philosophy is commonly described as having replaced the hylemorphic theory of bodies, grounded in the notions of matter, form and privation, with a corpuscular theory of matter, in which material corpuscles obey laws of motion. But how this substitution took place, the various research programs associated to it, and the tensions that might exist between the mathematical description of phenomena, their corpuscular reduction and their empirical investigation, have yet to be explored. This is what is at stake in the papers of the second part, "Matter, Motion, Physics and Mathematics."

Navarro focuses on the little-known Valencian physician Bernat d'Olesa Rovera. His *Summa totius philosophiae et medicinae* (1536) belongs to the as yet only partly explored category of books that were undoubtedly conceived in an Aristotelian atmosphere, but that open the way for corpuscular explanations, in particular with respect to what was known among Aristotelians as the problem of *mixtio*. After exploring some aspects of Olesa's theories, Navarro demonstrates that no literary continuity exists between Olesa and two later Spanish alleged corpuscularists, Gomez Pereira and Francisco Valles, but that none of them are to be classified among corpuscularists. Thus, he concludes, d'Olesa remains an intriguing exception with no intellectual offspring.

In a sense, Palmerino deals with the same problem as Navarro, namely the problem of continuity between the Aristotelians and the new mechanical philosophers, but with a completely different method. Instead of focusing on what turns out to be a singularity, she emphasizes that certain structures of thought concerning both the theory of matter and the science of motion endure throughout the seventeenth century, no matter which camp. She first shows that authors as different as Galileo, Roderigo de Arriaga, Sébastien Basson, Pierre Gassendi, Jean Chrysostome Magnen, Fabri or Libertus Fromondus assumed what she calls the isomorphism theory, namely the theory according to which what holds for the structure of space, time and motion, holds for the structure of matter as well, "structure" referring here to the alleged continuity or discontinuity of these magnitudes. This is why these authors treated acceleration and deceleration of motion on the one hand, rarefaction and condensation

of matter on the other hand, as if they were similar phenomena. Second, through a careful reconstruction, she explains when, how and why, towards the end of the seventeenth century, the isomorphism theory was called into question by Newton. As she argues finally, this was not a definitive victory, however, since Newton's pupil John Keill reasserted the isomorphism of space, time and matter in a course on natural philosophy held in Oxford during the first decade of the eighteenth century.

While Palmerino emphasizes the existence of structures of thought common to both Aristotelians and mechanical philosophers, de Buzon points out differences that exist between two putative spokesmen for mechanical philosophy by confronting Isaac Beeckman's and Descartes' principles of conservation of motion. Inasmuch as Beeckman had touched on the three laws of nature proposed by Descartes in *Le monde*, namely the persistence of motion in a vacuum, the persistence of direction, and the global conservation of motion in impact, it is a difficult question to determine what Descartes exactly borrowed from Beeckman. De Buzon's angle of attack is however somewhat different: he wants to point out that Beeckman's laws and Descartes' laws were not only conceptually distinct, but determined by different conceptions of the relationship between physics and mathematics. Notwithstanding the unsystematic state of Beeckman's *Journal*, the main characteristic of his way of dealing with the problem of motion is his reliance on geometric considerations, well illustrated by his principle of isoperimetric figures. On the contrary, Descartes insists that his laws of motion are laws of nature, motion having become the first object of Cartesian science. By way of conclusion, de Buzon can thus explain why the expression *physico-mathematicus*, well-attested by Beeckman, has disappeared by the time of Descartes: it is because physics and mathematics have for him fundamentally the same object.

With Malet's paper, we are not confronted with the continuity issue, but rather with the vexing question of national traditions. Traditionally, the English and French traditions in natural philosophy are contrasted, the first being supposedly more experimental, the second more mathematical. Malet begins with a discussion of Blaise Pascal's hydrostatics that ends up qualifying his alleged commitment to mixed mathematics. In contrast, the manuscript *Hydrostatica* by James Gregorie (1638–1675) is written in a clearly mathematical style with respect to its concepts, to its deductive organization, and to the subordinate place it devotes to experiments. This raises the question of the interplay of mathematics and experiment that Malet analyses in the case of the doll experiment that was used in different ways in three different hydrostatical treatises, Gregorie's *Hydrostatica* of course, Robert Boyle's *Hydrostatical Paradoxes* (1666) and Willem Jacob Gravesande's *Mathematical Elements of Natural Philosophy, Confirmed by Experiments* (1715). Finally, the question of the discussions concerning the status of hydrostatics, between mathematics and experimental philosophy, is contextualized both with respect to the Royal Society and to the Scottish Enlightenment.

The third and last part of this book, "Mechanical Philosophy Applied," is devoted to the mechanization of specific domains. It is now established that the successes of the mechanical philosophy were actually few in number and that in some domains, most notably chemistry and biology, it failed to provide satisfactory accounts of phenomena.

One can consequently wonder what were the strategies and attitudes in these domains: did the old ways of thinking last, or were new alternative models looked for? As in the second part of this book, the nature of mechanization and the question of the relationship between mechanical philosophers and their Aristotelian predecessors (or contemporaries) is at issue, but this time viewed through the constraints imposed by the domains of application.

The relevance of the object under consideration is central to Gómez's paper. Gómez concentrates on Galileo's mechanization of light and relates it to the well-known Galilean shift from physical (extended) atoms to mathematical (non-extended) atoms. She first discusses the intellectual context and theoretical implications of Galileo's letter to Piero Dini from 23 March 1615, where one finds a description of a very spiritual substance that is diffused through the whole universe and animates it. *Il saggiatore* presents a mixed and transitory stage, since bodies are composed of extended particles, while light is composed of non-extended atoms; this theory allows Galileo to account for what are, according to him, the peculiarities of light, in particular its capacity to travel instantaneously. Finally, in the *Discorsi*, Galileo generalized his idea of non-extended atoms to all kinds of bodies. The paradox at this point is that he uses such entities, normally confined to mathematics, to compose physical bodies, with one of the consequences being that, now, a set velocity is ascribed to light.

By focusing on meteorology, Martin succeeds in giving a reappraisal of Descartes' enterprise in this field. Since Étienne Gilson, it has been known that the structure and topics of the Cartesian *Météores* are quite similar to their Aristotelian counterparts; however, it was assumed that some differences exist as well, inasmuch as *Météores* illustrate some general characteristics of Descartes' physics, like the dispensability of substantial forms and final causes. A closer examination of the major Aristotelian treatises on meteorology shows that the situation is, once again, somewhat more complicated. Craig begins by an assessment of the specificity of meteorology according to Aristotle himself: because it is a field dedicated to natural phenomena that lack clear order, it is best understood by material and efficient causes rather than formal and final ones. In the Renaissance, the intractability of meteorological phenomena even leads Agostino Nifo and Pietro Pomponazzi to insist that meteorology cannot provide true causes, but only conjectures. In the early seventeenth century, Aristotelian commentators like John Poinsot, Eustachius a Sancto Paulo, Libertus Fromondus, Francesco Resta or Daniel Sennert were divided on the question of knowing if final and formal causes should be used in meteorology, the most interesting case being the one of the Jesuit Niccolò Cabeo, who explicitly wrote a comment on Aristotelian meteorology (1646) because he considered that neither form and privation nor final and formal causes were needed in this field. In that sense, Craig concludes, Descartes' meteorology should not be read as a revolutionary work, but rather as a contribution to an on-going debate on the nature of meteors and on the methods to be applied in their study.

Manning's paper is devoted to a key question for another applied part of Cartesian natural philosophy, namely medicine: the human body is described as a machine, but can one say that a machine is just a corporeal substance? And how would it be

possible to speak of sickness and health if human bodies were only machines in this sense? After having recalled that the interests of medicine and of natural philosophy were closely linked in the seventeenth century in general and in the Cartesian corpus in particular, Manning comments in a detailed way on the two texts that are, according to him, pertinent for this question. First, he examines what the *Traité de l'homme* tells us about machines and about the human bodies. Second, commenting the famous text of the *Meditatio VI* on a body suffering from dropsy, Manning suggests that the expression *denominatio extrinseca* that it uses should be traced back to its scholastic origins. A close analysis of the couple *denominatio extrinsica/denominatio intrinseca* finally leads him to the conclusion that the human body cannot be said to be healthy except in relation to the human being, that is the union of a body with a mind.

With Lambert, we continue with the human body, but this time not reflected in the mind of a philosopher, but rather put into the hands of the *démonstrateur* in anatomy and surgery at the *Jardin du Roi* in a period of conflict between the medical and the surgical corporations, Pierre Dionis (1643–1718). According to Dionis's *Anatomie de l'homme suivant la circulation du sang et les nouvelles découvertes* (1690), the art of surgery is founded in the science of anatomy, and the science of anatomy is governed by mechanical principles: dissection is legitimate for understanding the living bodies; the structure should explain the function of the organs, whether this structure is apparent or to be revealed by micrography; lastly, effect is proportionate to its cause. Hence, it is not surprising that Dionis defends a truly mechanical program consisting in analyzing the human body without appealing to faculties and specific substances. But, as many others, as Lambert thoroughly explains, Dionis sometimes walks into the common traps of finality when he tries to connect structures and functions of the human body.

Finally, Franckowiak examines the reaction of Du Clos to Boyle's attempt to find in mechanical philosophy some foundations for chemistry as well as the principles of his own chemical philosophy. An early member of the class of physics of the *Académie royale des sciences*, Samuel Cottereau Du Clos (1598–1685) was charged with examining Boyle's *Tentamina chimica.* For him this was the opportunity to give what could be seen as the answer to the "vulgar chemist" Boyle: he reproached Boyle for not having taken experiments seriously and for not having found the proper causes of the disintegration of saltpeter. Du Clos actually formulated a natural philosophy that combines the actions of a mechanical principle (the passive and corporeal "body"), a chemical principle (the active and incorporeal "nature") and a mediating principle (the igneous "spirit"). In that sense, he wished paradoxically to defend through his visible and sensory experiments a natural philosophy relying on invisible and spiritual principles that, according to Franckowiak, could be interpreted as complementary to mechanical philosophy.

It is usual to conclude introductions to books that, like this one, gather a collection of essays, with an ode to the inexhaustible diversity of historical case studies. We think however that, in the present case, it is possible to say something more substantial. Whichever definition you admit, the mechanical philosophy was clearly a polemical category. Many of the essays in this collection explore exactly that, and the role that that polemic played in the debate over Aristotelian natural philosophy.

In doing so, they deal not only with the analysis of central texts of the central figures in the tradition, but with many of the lesser figures, the foot soldiers, as it were, of the Scientific Revolution. But to appreciate fully the opposition between the mechanical philosophy and the Aristotelian orthodoxy, one must see the variety of domains in which the opposition was played out. For that reason a number of the essays deal with the extension of mechanist ideas to domains where their application may not be quite so obvious and unproblematic. While we have certainly not exhausted the infinite diversity of historical case studies, this collection defends and illustrates a certain way of writing the history of the mechanization of natural philosophy.