Marco Sgarbi

RENAISSANCE ARISTOTELIANISM AND THE SCIENTIFIC REVOLUTION

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ESSAY REVIEW

RENAISSANCE ARISTOTELIANISM AND THE SCIENTIFIC REVOLUTION

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1. Historiographical Biases

David Wootton's *The Invention of Science. A New History of the Scientific Revolution*[1] is the most significant work on the Scientific Revolution since the publication of Steven Shapin's *The Scientific Revolution* in 1996. However, whereas for Shapin "there was no such thing as the Scientific Revolution," that is "a coherent, cataclysmic, and climatic event that fundamentally and irrevocably changed what people knew about the natural world and how they secured proper knowledge of that world,"[2] for Wootton not only was there a Scientific Revolution, but it "was a single transformative process [...] of several distinct types of change overlapping and interlocking with each other."[3]

The two theses, like their methodologies, are opposites. Wootton's book is written against the historiographical approach advocated by Shapin, and with him Simon Schaffer, Nick Wilding and many others generally characterized as relativist historians. A relativist approach would render "the Scientific Revolution totally invisible,"[4] and science entirely, purely and simply a "social construc-

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1 London, Allen Lane, 2015. Hereafter, referenced in abbreviated form (W), followed by page numbers.

2 S. Shapin, *The Scientific Revolution*, Chicago, The University of Chicago Press, 1996, p. 1.

3 W, 566.

4 W, 591.

tion." [5] Wootton views his own position as constructivist rather than relativist, however, because "science, as a method and practice, is a social construct [...] but science as a system of knowledge is more than a social construct because it is successful, because it fits with reality." [6] In this manner Wootton distances himself from those historians of science who question the existence of a single and uniform intellectual movement called "the Scientific Revolution," of an entity called "modern science," and of a method that can truly be considered "scientific." He believes in each one of these conceptions, but he does share with these historians some fundamental ideas that sometimes seem to undermine his historical narrative.

Almost all histories of science of the period between 1500 and 1700 are founded upon two closely interlinked historiographical assumptions. The first is that the great advancements in science happened mainly in the seventeenth century in opposition to a stagnating Medieval and Renaissance thought. The second assumption is that such developments were possible within an anti-Aristotelian movement. As a matter of fact, Wootton embraces these historiographical biases: he explicitly writes that "modern science was invented between 1572, when Tycho Brahe saw a nova, or new star, and 1704, when Newton published his *Opticks*." Moreover, his book presents numerous statements according to which the Scientific Revolution was a revolt against Aristotelianism.

There are at least three reasons for the origin of these biases. The first is that historians have all too frequently given credence to the self-proclaimed novelty and anti-Aristotelianism of the so-called moderns, who are in fact known to historiography as *novatores*. Already from the titles of their works one senses the wind of change that appears to characterize a decisive programmatic turning away from the past, from the Aristotelian tradition especially.[7] Both the constructivist Wootton that the relativist Shapin, like many others, agree on this aspect. How much these self-declarations of originality correspond to the truth or in fact constitute a case of blatant self-deception and cultural propaganda is an open debate.[8] Often in the history of thought, philosophers and scientists have declared themselves to be revolutionaries or subverters of the *status quo* in order to establish their ideas, exalt their genius and disseminate their thought. Is it possible to rely on these claims of novelty and anti-Aristotelianism, or are we in fact misinformed by the moderns? Clearly one cannot question the existence of the scientific discoveries of the time,

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[5] W, 517. On these characters of post-modern history of science, cf. H. Floris Cohen, *The Scientific Revolution. An Historiographical Inquiry*, Chicago, The University of Chicago Press, 1994, pp. 151-152; L. Daston, K. Park, *Introduction*, in *The Cambridge History of Science. Volume 3. Early Modern Science*, Cambridge, Cambridge University Press, 2006, pp. 12-13.

[6] W, 540.

[7] Cf. L. Thorndike, *Newness and Craving for Novelty in Seventeenth-Century Science and Medicine*, «Journal of the History of Ideas», 4, 1951, pp. 584-598.

[8] Cf. E. Panofsky, *"Renaissance" – Self-Definition or Self-Deception?*, in *Renaissance and Renascences in Western Art*, New York, Harper&Row, 1972, pp. 1-41.

which were real and had a huge impact on the history of science. What one must ask is whether these findings and their impact were truly revolutionary. Some doubt may be raised reading the historiographical reconstructions of the period. Generally, authors like Galilei were seen as *novatores*, but this appellation did not necessarily have the positive connotations it enjoys today. Historian Daniel Georg Morhof, for instance, wrote in his *Polyhistor* (1688) that most of the moderns

> […] attempted a rebellion and strove to conquer the tyranny of the Peripatetics. […] In addition these innovators do not share the same genius; some of them are mad in their reasoning, some are entirely inept and have introduced nothing new into philosophy apart from various terminologies […]. The quest for a little fame obsessed many, but only a few were led by the study of truth.[9]

Fame and glory, more than the truth, moved according to Morhof these *novatores* to criticize Aristotelianism. Emphasizing the original character of their research would not have been instrumental to the quest for the truth in opposition to the falsities of the ancients, rather it would have been a symptom of the sense of rivalry and competitiveness among colleagues racing to unearth new discoveries that could be remembered in the annals of the history of science. Of course, even Morhof's testimony cannot be taken as absolute truth, but it is evidence of a different feeling towards developments of science in those years.

This self-portrait of the moderns as anti-Aristotelian philosophers and scientists led the twentieth-century historiographical research not only to consider the alleged Scientific Revolution as a reaction against Aristotelianism, but also to neglect the study of Aristotelianism itself within the intellectual framework in which to understand the innovations and discoveries of the "new science." This is the second main reason for the historiographical biases. Even those who dealt with Renaissance Aristotelianism and its relation to modern science in a highly sophisticated way denied any influence of the former on the latter.[10] These studies, however, focus mainly on Aristotelianism in the universities, where professors were obliged to teach the Aristotelian thought according to specific canons and standards, and for this reason scholars have always thought that the Aristotelian culture in the Renaissance was stagnant.

If one looks at the fortune of the Aristotelian tradition beyond universities and ecclesiastic schools,[11] it is possible to find a more vibrant culture that is open to the new scientific and technical discoveries. It is no coincidence, therefore, that two of the most original and innovative Aristotelians mentioned by Wootton, Alessandro Piccolomini and Leonardo Garzoni, worked mainly outside the uni-

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9 D. Morhof, *Polyhistor Literarius, Philosophicus et Practicus*, Lübeck, Böckmann, 1688, p. 108.

10 Cf. Ch. B. Schmitt, *Experience and Experiment: A Comparison of Zabarella's View with Galileo's in* De Motu, «Studies in the Renaissance», 16, 1969, pp. 80-138.

11 D. A. Lines, *Beyond Latin in Renaissance Philosophy: A Plea for New Critical Perspectives*, «Intellectual History Review», 25, 2015, pp. 373-389.

versity and wrote in the vernacular. How the anti-Aristotelian paradigm operates in Wootton's research is clear in Garzoni's case. Garzoni is a real puzzle for Wootton. While recognizing that Garzoni's treatises "are the first major work of modern experimental science," Wootton adds that the inventor of the new magnetic science was actually Gilbert, not Garzoni. Indeed, in this specific case, "chronology is misleading" because "for crucial respects [Garzoni's treatises] are simply a continuation of the erratic medieval tradition of experimentation […] their conceptual apparatus is Aristotelian, and they seek to address a gap or anomaly in the Aristotelian scheme of knowledge." [12] But why, instead of excluding Garzoni from the narrative of the Scientific Revolution or from the developments of "modern science" just because he was Aristotelian, do we not try to include him and imagine that even these atypical Aristotelians might have made significant contributions to the advancement of knowledge? In general, as in this case, historiography has dealt only sporadically with these forms of philosophy and science, not to mention this Aristotelianism,[13] focusing rather on the *novatores* of philosophy like Bernardino Telesio, Giordano Bruno, Tommaso Campanella and others, but there is a whole other underground world to be explored that it is coming to light as we speak and promises, at least in part, to shed new light on developments in science.

The third reason, only recently recognized,[14] is that, when one speaks of Scientific Revolution in general one is dealing with the substitution of one culture with another: the philosophy of the *novatores* that takes over from Aristotelian philosophy, and "modern science" that replaces Aristotelian *scientia*.[15] As we have already mentioned, the majority of the histories of philosophy and science, like Wootton's, were written following this paradigm.[16] Nowadays, thanks to Daniel Garber's meticulous clarifications, we know that it is no longer so: neither Bacon's experimental philosophy nor Galilei's mathematicism, Descartes's mechanicism or even Newton's physics were capable of establishing themselves globally and supplant Aristotelianism. We can therefore reasonably argue that "the diversity

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[12] W, 328.

[13] Cf. L. Olschki, *Geschichte der neusprachlichen wissenschaftlichen Literatur. Bildung und Wissenschaft im Zeitalter der Renaissance*, Leipzig-Florence-Rome-Geneva, Olschki, 1922; S. Caroti, *L'"Aristotele italiano" di Alessandro Piccolomini: un progetto sistematico di filosofia naturale in volgare a metà '500*, in A. Calzona, F. P. Fiore, A. Tenenti, C. Vasoli (eds.), *Il volgare come lingua di cultura dal Trecento al Cinquecento*, Florence, Leo S. Olschki, 2003, pp. 361-401.

[14] D. Garber, *Galileo, Newton and All That: If It Wasn't a Scientific Revolution, What Was It? (A Manifesto)*, «Circumscribere. International Journal for the History of Science», 7, 2009, pp. 9-18; D. Garber, *Why the Scientific Revolution Wasn't a Scientific Revolution, and Why It Matters*, in R. Richards, L. Daston (eds.), *Kuhn's Structure of Scientific Revolutions at Fifty*, Chicago, University of Chicago Press, 2016, pp. 133-148.

[15] Cf. *Scientia*, in J. Kraye, G. A. Rogers, T. Sorell (eds.), *Early Modern Philosophy Seventeenth-Century Thinkers on Demonstrative Knowledge from First Principles*, Dordrecht, Springer, 2010.

[16] W, 24-25.

of alternative anti-Aristotelian programs that blossomed in the late sixteenth and early seventeenth centuries never completely sorted itself out in a single alternative to the Aristotelian program, nothing that could be called *the* new science." [17] Perhaps it would be more appropriate to focus on the transmission, modification and exploitation of the Aristotelian tradition within an intellectual framework in continuous change and evolution, such as early modernity was.

Besides all these general historiographical biases, there are many that are more detailed and just as pervasive. One of them concerns the origin of the Scientific Revolution. It is traced back to Galileo Galilei, who has the merit of (1) having fought dogmatic Aristotelianism; (2) having founded mechanics; (3) having applied mathematics to the study of natural phenomena; (4) having provided indisputable evidence for the validity of Copernicus' heliocentric theory with the discovery of Venus's phases; (5) having reconciled celestial and terrestrial physics with his numerous astronomical observations. Here, too, Wootton remains faithful to the historiographical tradition and sees Galilei as the great revolutionary.[18]

This historical picture of Galilei is nowadays contested and must be revised. There is a growing demand among scholars for a greater contextualization of his thought to allow the hidden traces of shared knowledge to be reconstructed and thereby the originality of his thinking and the scale of his contribution to the new discoveries to be recognized in a more truthful manner,[19] beyond the facile proclamations of the propagandists. However, "even today the fact that the young Galileo composed a number of Aristotelian treatises is often considered as merely the excusable lapse of an immature scientist." [20] Not only, historiography tends "to portray medieval Aristotelian scholasticism merely as the counter position against which Galileo's theory of motion gained its profile as new science, neglecting the potential of Aristotelianism as a generic knowledge resource available to Galileo and his contemporaries." [21] It misconstrues the idea that "any attempt to create a theory of nature as general as Aristotelian physics has to start from this basic body of knowledge, even if its goal is to revise the Aristotelian system." [22] The Aristotelianism and the intellectual background from which the stories of scientists like Galilei emerged should not be considered an obstacle to be overcome, rather fertile soil for new discoveries. Indeed, of Galilei's Aristotelian background or his role as an astrologer following in the footsteps of a long Medieval and Renaissance

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[17] D. Garber, *Why the Scientific Revolution Wasn't a Scientific Revolution, and Why It Matters*, cit., p. 142.

[18] W, 214-222, 224-228.

[19] J. Büttner, P. Damerow, J. Renn, *Traces of an Invisible Giant: Shared Knowledge in Galileo's Unpublished Treatises*, in *Largo campo di filosofare: Eurosymposium Galileo 2001*, Orotava, Fundación Canaria Orotava de Historia de la Ciencia, 2001, pp. 183-201.

[20] *Ibid.*, p. 188.

[21] *Ibid.*, p. 190.

[22] *Ibid.*, p. 189.

tradition,[23] there are no traces in Wootton's book. Nor could there be any trace, in fact, because the whole of his book "is an argument against the continuity thesis."[24] If one aims to defend the existence of a revolution in science, one cannot at the same time support the continuity thesis. It is true, as Wootton says, that continuity thesis in historiography tends to underestimate the subject under examination, resizing it to fit within its historical and intellectual context, but it is through the re-contextualization of the alleged "Scientific Revolution" that one can appreciate even the smallest contributions to the advancement of knowledge between 1500 and 1700.

Many questions arise. Can one truly call "revolution" something that happened over a period of more than a hundred years? Wootton gives a positive answer: "between 1600 and 1733 (or so – the process was more advanced in England than elsewhere) the intellectual world of the educated elite changed more rapidly than at any time in previous history."[25] For this reason we had a revolution. If so, however, can one still legitimately call a process that concerns a clique, a small circle of intellectuals, a "revolution"? The investigations of cultural history have shown that between 1500 and 1800 there was no substantial change in the popular culture of the ordinary people, that is for the whole non-elite. Hence, even if one could admit the existence of a revolution in science, the question should be how much was it revolutionary and for who?

What we have pointed to so far should not be considered real weaknesses, rather the flattening of a historiographical trend more committed to dwelling on methodological debates and writing new historical narratives with old material, rather than uncovering new historical data. Wootton, however, develops an original methodology that constitutes the most significant aspect of his important research. His novelty consists in looking for the revolution in language that must have accompanied the revolution in science: "the revolution in language is indeed the best evidence that there really was a revolution in science." In other words, what one should look for is the emergence of new languages, because "they represent transformations in what people can think and how they can conceptualize their world."[26] With transformations of language he means not only the introduction of new words, but also new meanings acquired by old terms which are often unrelated to the original meanings. This argues in favour of a discontinuist approach. If new words and new meanings are found, the reason is that most of the time they designate new things or new ways of thinking.

This approach to the history of science through the history of words has proved fruitful, and Wootton applies it to almost seventeen chapters of his book.

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23 Among the various works cf. H. D. Rutkin, *Galileo Astrologer: Astrology and Mathematical Practice in the Late-Sixteenth and Early-Seventeenth Centuries*, «Galileana», 2, 2005, pp. 107-143.

24 W, 573.

25 W, 11.

26 W, 48-49.

At times Wootton strays from the history of the words to the history of concepts. In dealing with the term "evidence," for example, he writes that "it would be wrong, however, to concentrate solely on the word 'evidence' rather than the concept which it expresses, for if we do so we will miss a crucial development."[27] This shift from words to concepts occurs frequently and speaks more in favour of continuity than discontinuity. While the introduction of a new word can be documented through a more or less exhaustive census of lexicographical repertories, the concept behind the word can be traced back as far as the imagination of the historian can find relevant similarities or analogies. A revolution is therefore much harder to determine through concepts than through words, hence the lexicographical approach would seem better suited to the purpose. There is little doubt that this vein of inquiry shall be further explored in the near future.

2. Mathematization and Constructivism

Joseph Glanvill summarizes the key idea of Wootton's book: "The Aristotelian Philosophy is inept for New discoveries [...] There is an America of secrets and [an] unknown Peru of Nature."[28] This sentence on the one hand characterizes the anti-Aristotelianism which imbues the "modern science," while on the other it connects the new concept of "scientific discovery" to recent geographical discoveries, a connection without which, according to Wootton, there would have been no revolution at all.

The discovery of America opened up a whole new world for science, and Wootton in fact devotes an entire chapter to the word and concept of "discovery." Prior to 1492, "the primary objective of Renaissance intellectuals was to recover the lost culture of the past, not to establish new knowledge of their own [...] there was no such thing as new knowledge. What looked like new knowledge was, consequently, simply old knowledge which had been mislaid, and history was assumed to go round in circles."[29] By means of semantic study of the use of the word "discovery," however, Wootton shows how it assumes a new meaning and becomes a metascientific idea. One can say that "discovery" constitutes the true "transcendental" of science, it "is the crucial precondition for systematic innovation in the knowledge of nature," and in fact there cannot be a logic of innovation without first assuming the concept of "discovery." The instatement of "discovery" as a culturally and socially shared idea made it possible for the process of innovation to be recognized and understood as a positive value in opposition to authority. It was thanks to the new geographic discoveries that for the first time the empirical data, or experience, could confute previously established knowledge.

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[27] W, 419. The same is said about the "fact", cf. W, 297.

[28] W, 39.

[29] W, 73-74.

The discovery of America, for instance, showed clearly and empirically that life at the tropics was possible, in direct opposition to the view propounded by Aristotle.[30] This silent revolution, more than the Copernican theory, produced the kind of crisis in the Aristotelian cosmology that later led Tycho Brahe (1572) and Giordano Bruno (1584) to defend, respectively, the corruptibility of the heavens and the infinity of the universe.

The introduction of the idea of "discovery" in the early modern conceptual framework is one of the two major causes that triggered the process of the Scientific Revolution. The second is the so-called mathematization of the sublunary world, which started with Leon Battista Alberti.[31] Wootton writes that "the seventeenth-century mathematization of the world was long in preparation," and that "perspective painting, ballistics, fortification, cartography and navigation prepared the ground for Galileo, Descartes and Newton."[32] Indeed, there is a continuous line that connects Alberti with Galilei, passing through Leonardo Da Vinci and Niccolò Tartaglia. To start with, each one of these authors was an engineer who developed his theories in close liaison with artisans. More importantly, however, according to Wootton, all these intellectuals supported the view that mathematics could aspire to the highest degree of certainty because it considered the mathematical and geometrical forms without matter, that is without the accidental component.

Historians of science from Alexandre Koyré and Ernst Cassirer have always maintained that this conception involved an adherence to some particular kind of Platonism. Yet this notion is the central idea of Aristotle's second book of the *Metaphysics*, where he states that since the subject of physics is matter, namely something accidental, it cannot aspire to the highest degree of certainty and precision of mathematics. It is important to focus on this point because the persistent idea of a Platonic perspective has often led historians to the simplistic assumption that anyone who trusts mathematics is Platonic and therefore anti-Aristotelian. But the inference is not so direct and explicit. He who "spoke in praise of the mathematical sciences" not always "praised them by denigrating the Aristotelian philosophy taught in the universities," as Wootton writes in Regiomontanus's case.

There are plenty of cases in the Renaissance in which Aristotelianism was more or less combined with mathematics. Some examples are Nicolò Tartaglia, Alessandro Piccolomini, Pietro Catena and others who produced highly influential works in which Aristotelian physics was described through mathematical tools and Peripatetic conceptuality, logic and ideas were seen as complementary to the mathematical investigation. Of course, one can doubt that these mathematicians were "truly" Aristotelian, but Tartaglia discusses, comments and partially translates the pseudo-Aristotelian mechanics, Piccolomini is arguably the most impor-

[30] W, 136.

[31] W, 200.

[32] W, 209.

tant vulgarizer of Aristotle in the Renaissance and Catena wrote a work on the identity between Aristotelian logic and mathematical reasoning. They diverge in some points from Aristotle, but they do not stand outside the long history of the Aristotelian tradition. The Renaissance mathematical movement cannot be presented as anti-Aristotelian without qualification.

In the central part of his book, Wootton deals with the constituent elements of the Scientific Revolution which purportedly contributed to the substitution of a new world of quantity for the Aristotelian world of qualities: from causes and essences to "facts," "experiments," "laws," "hypotheses/theories," "evidence and judgement." In Wootton's view, the "facts" represent a new way of knowledge grounded in experience, and must be distinguished from the phenomena investigated by the old philosophy. Facts refer to evidence and explain *how* a thing is, while phenomena refer to a cause and explain *why* a thing is. Herein lies the key difference between the Aristotelian *scientia* and the "modern science." This distinction reflects the difference between the Latin term "factum" and the English term "fact": "a *factum* requires an agent, a fact does not." [33] In other words, to know a *factum* one needs to know the causes, whereas the knowledge of the cause is not necessary to know a "fact." Thus, following Knelem Digby, Wootton states that "we can establish 'the verity of the fact' […] without having knowledge of the cause." [34] The new science focuses on facts because they set the standards "for judging the reliability of testimony," in particular the testimony of experience against authority.

However, Wootton's methodology of the history of language also leads to the discovery of a number of exceptions in the early modern age in which the "fact" coincides with something done or made, that is something that refers to an agent, to the point that he is compelled to admit that the word "fact" in its modern sense, that is without the reference to the agent, "becomes respectable in English only after 1661." [35] In this context, he abandons his methodological approach and states that "the words are one thing, the concepts are another. The word fact tells us very little about the establishing and refuting of facts." [36] Beyond words there is something more, the concept, which should in fact determine the victory of the "fact" without agent. Indeed, in Wootton's historical narrative, if one does not acknowledge the distinction between the *factum* and the fact, one cannot understand why the fact became so important for modern science, why it deals with experience and why it led to a new epistemology that characterizes a revolutionary movement against the Aristotelian theory of knowledge. Also in this case the break with tradition and the opposition to Aristotelianism seem to be too strong, and the willingness to distinguish the fact from the *factum* prevents recognition

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33 W, 284.

34 W, 287.

35 W, 297.

36 W, 297.

of the various dynamics at work in the broadest cultural context from which the alleged Scientific Revolution is thought to emerge.

In the *De antiquissima Italiorum sapientia*, Giambattista Vico offers another reliable reconstruction of the instatement of the "fact" in the "modern science." As Vico reminds us, the Latins and Scholastics identified the *verum* with the *factum* in Wootton's sense, that is something that is made. This identification is possible because the agent of the *factum* knows all the causes, and to know the causes means to know the truth. Therefore, for the maker, *verum* and *factum* coincide. It is clear, then, that knowledge of truth pertains only to God, who made and created all things, while the human mind can know only some elements, and even then by analogy. Therefore, Vico writes, when the human being investigates the nature of things, it becomes aware of the impossibility of grasping the essences because it does not know how things are constituted, and becomes conscious of the limits of the mind. Instead of falling into a pessimistic scepticism, the human being exploits this weakness of the mind, and "by abstraction […] feigns a world of numbers and forms, which would embrace in itself the universe." [37] Thus "the physicist, being incapable of defining the things according to the truth, that is by attributing to each thing its nature and making it actually (this is possible for God, but impossible for man)" – because it does not know certainly "the elements from which the things receive existence" – it "has begotten two sciences that are most useful to society – arithmetic and geometry – and from these, in turn, it has begotten mechanics, the parent of all the arts necessary to mankind." [38] Therefore, Vico explains, "human science is born of a defect of the mind – namely, of its extreme littleness – in consequence of which it is external to all things, contains nothing of what is desires to know, and so cannot produce the truth which it seeks to ascertain." On the contrary, "the most certain sciences are those which expiate the defect in why they originate, and which resemble divine science by the creative activity which they involve." [39] Vico's story shows that the culture of facts within science is born when the products of the mind, the *facta*, have been used not only as tools for reading reality, but when they have been conceived, by analogy, as constituent elements of reality itself and of the nature of things.

Vico's historical reconstruction acknowledges the importance of the mathematization of the world maintained by Wootton and others without resorting to some artificial and labile distinction – at least from the standpoint of the history of the term – between the fact without agent and the *factum* with agent. At the core of this conception, according to which one knows what it makes, there is the idea that the human being cannot directly know the truth. This perspective has established itself in opposition to Platonism and Scholasticism and in line with

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[37] G. Vico, *De Antiquissima Italorum Sapientia*, translated by L. M. Palmer, Ithaca-London, Cornell University Press, 1988, p. 47. Translation revised.

[38] *Ibid*., p. 52.

[39] *Ibid*.

the new Renaissance naturalistic Aristotelianism, especially that inaugurated by Pietro Pomponazzi. It is a well-known fact that in his *De immortalitate animae* Pomponazzi denies human beings the theoretical capacity through which the mind can know the causes, the principles and the essences of nature and of things. Only very few human beings can acquire this kind of contemplative and speculative knowledge. This led to the conclusion that the proper dimension of the human being is the practical one, that of morals and actions: human beings know what they do because the principle of action is in themselves and thus they know all the cause of the "facts" that they made. Reflection on the narrow intellectual capacities of the mind triggered a series of considerations on what the life and the activity proper to the human being were. In general, Platonics and Scholastics still believed that the proper activity of the human being was theoretical, while many Aristotelians started to think that the proper activity was practical, thus opening the question about what the mind could know. For instance the Aristotelian Sperone Speroni, in his *Dialogo della vita attiva e contemplativa* (1542), states that it is hard to have an insight into the essence of things and that the mind acquires a more precise and truthful knowledge by considering only *how* things happen in the world or *how* they are made.[40] For Speroni to recognize the narrowness of the human mind does not mean to defend a sceptical attitude, which promoted the idea of the vanity of knowledge. Rather this acknowledgement led to the elaboration of supplementary and corrective tools for the mind. Among these, not surprisingly, Speroni mentions mathematical sciences and in particular geometry.

The emphasis on the limited capacity of mind within Aristotelianism, especially its vernacular embodiment, generated almost a total disinterest towards metaphysics, focusing rather on natural and moral philosophy. Also within these two branches of philosophy we can recognize a predisposition towards disciplines dealing with facts. For instance, in the field of natural philosophy, we can find copious works concerning mechanics, namely ballistics, the science of weights or fortifications, etc., that is disciplines useful for engineers, soldiers, architects, and artisans.[41] We also find great interest in meteorology,[42] that is the science of floods, tides, fires, earthquakes, etc., which provided immediately applicable notions for understanding nature which could prove decisive in agriculture or open-sea voyages. In the field of moral philosophy, we see the production of a number of works on ethical and political precepts, in particular on *how* to instruct soldiers, leaders and princes or on *how* to command people or armies.[43]

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[40] Cf. S. Speroni, *Opere*, Venice, Occhi, 1740, vol. 2, p. 496.

[41] Cf. M. Sgarbi, *Aristotele per artigiani, ingegneri e architetti*, «Philosophical Readings», 2, 2016, pp. 67-78.

[42] Cf. C. Martin, *Meteorology for Courtiers and Ladies: Vernacular Aristotelianism in Renaissance Italy*, «Philosophical Readings», 2, 2012, pp. 3-14.

[43] This kind of explanation is not typical only of natural philosophy, but also of ethics and politics. The most famous case is Nicolò Machiavelli, who does not aim to give a causal explanation of which is the best political model, rather it is more important for him to explain

The focus of these disciplines was not on the discovery of the *why* or of the essence of natural or human nature, because this knowledge was not proper or at least possible to human beings, rather on the *how*. The search for the "*how*" rather than the "*why*" allowed an immediate applicability of knowledge that rarely could be achieved by means of a mere metaphysical survey of essence.

Tartaglia is a case in point. His obsessive focus on the solution, by means of mathematics, of practical problems common among artisans, engineers and architects, led to a simple description of the physical phenomena.[44] The most important aspect was to explain *how* phenomena happened and from these descriptions *how* to formulate useful laws to test and replicate the phenomena. Equally emblematic is the case of Galileo Galilei, who at the very beginning of his career aimed to solve practical problems related to the scale, floating bodies and tides. Later he applied mathematics to the whole universe in his *Dialogo sopra i massimi sistemi del mondo* and the terrestrial physical phenomena in the *Discorsi sopra due nuove scienze*, and in so doing founded modern mechanics.

The immediate consequence of the mathematization of the world, that is the world is made of "facts" understood as mathematical *facta* and therefore perfectly understandable by the human mind, is that knowing and operating are convertible, that is what one knows, one can do or make. The result is thus the application of known causes to produce effects in order to test the validity of the acquired knowledge. This led to another central claim of Wootton's book, that is the strict relationship between the fact and the experiment. The experiment is the simplest way of making strange facts plainer,[45] because if one can replicate the fact, this means that the causes of this fact are known and that the fact itself can be understood in the ordinary course of nature: the fact is no longer a strange fact but a plainer fact.

In other words, "the experiment is an artefact,"[46] in the sense that it is *factum* with an agent and for this reason the experiment can be understood as a reliable guide to how nature works. According to Wootton, Bacon was "the first person to insist as a matter of principle that knowledge of artefacts could count as knowledge of nature."[47] But William R. Newman and Perez Zagorin have shown that in Bacon there is no explicit endorsement of the theory of a maker's knowledge or of a constructivist principle.[48] The reason is simple: despite a sophisticated knowl-

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things *as* they are and *how* they are. Cf. N. Machiavelli, *The Prince*, Oxford, Oxford University Press, 2005, p. 5.

44 Cf. M. J. Henninger-Voss, *How the 'New Science' of Cannons Shook up the Aristotelian Cosmos*, «Journal of the History of Ideas», 63, 2002, pp. 371-397.

45 W, 300.

46 W, 322.

47 W, 323.

48 P. Zagorin, *Francis Bacon*, Princeton, Princeton University Press, 1999, pp. 38-39; W. R. Newman, *Promethean Ambition. Alchemy and the Quest to Perfect Nature*, Chicago, The University of Chicago Press, 2004, pp. 34-114. Antonio Pérez-Ramos himself admits that the Lord Chan-

edge of mechanics, Bacon was not proficient in mathematics. Only the descriptive tool of mathematics applied to natural philosophy and mechanics, now constituting one single science and not two separate disciplines, could demolish the distinction between art and nature, preternatural and natural.

Even if Bacon was not the revolutionary, Wootton's general claim that the distinction between art and nature collapsed after the mathematization of the world is more than plausible. However, it would be wrong to interpret this process of mathematization as a rehabilitation of Pythagorism or Platonism,[49] because if it is true that for these two philosophical movements numbers and mathematical entities represented the immutable forms that constituted the world, it is also true that they were mere objects of contemplation, a contemplation that from the sixteenth century onwards was doubly denied by the acknowledgement of the narrow capacities of the mind and the pragmatic value of knowledge.

At the same time, however, the fact is never merely empirical or accidental, but it must be a *factum*, otherwise its understandability would escape the control of the scientific laws, which are necessary to govern nature in a pragmatic perspective of knowledge. Amos Funkenstein was right when he stated that the "study of nature in the seventeenth century was neither predominantly idealistic nor empirical. It was first and foremost constructive, pragmatic in the radical sense. It would lead to the conviction that only the doable – at least in principle – is also understandable: *verum et factum convertuntur*."[50]

Thus "a new ideal of knowledge was born – the idea of knowledge-by-doing, or knowledge by construction."[51] A merely idealistic-Platonic or empirical framework could not have given rise to such a constructivist conception. Rather it emerged from the ashes of the Aristotelian tradition that recognized forms as constituent of matter.[52] It is the Aristotelian mathematicians like Tartaglia, who laid the foundations of the "modern concepts of scientific experiment, whether ideal or real, of a proof, which, in valorizing the activity of mathematical reasoning in the establishment of the objective fact, seeks […] to reproduce, or to imagine, the conditions of observability, which, if approximated to the ideal, are suitable to test the mathematical law."[53] Only an eclectic Aristotelian like Tart-

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cellor has never explicitly stated the theory of maker's knowledge. Cf. A. Pérez-Ramos, *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition*, Oxford, Oxford University Press, 1988, p. 92.

49 Cf. P. Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution*, Chicago, University of Chicago Press, 1995, pp. 8-9.

50 A. Funkenstein, *Theology and the Scientific Imagination from the Middle Ages to the Seventeenth Century*, Princeton, NJ, Princeton University Press, 1986, p. 178.

51 *Ibid*., p. 12.

52 Cf. D. Sepkoski, *Nominalism and Constructivism in Seventeenth-Century Mathematical Philosophy*, London-New York, Routledge, 2007.

53 Cf. A. De Pace, *Le matematiche e il mondo. Ricerche su un dibattito in Italia nella seconda metà del Cinquecento*, Milan, Franco Angeli, 1993, pp. 260-261.

aglia could affirm that "in natural events we know matter, the description, the quality and the quantity of every geometrical figure" [54] and that "all those things that are known as true in the mind, and are highest by demonstration abstracted by every matter, reasonably should happen also at the sight of matter (otherwise mathematics would be completely vain, of no benefit, that is profit for the human being)." [55]

The theoretical moment is always conjoined with the practical moment, so, Wootton writes, "science is an interactive process between *theory* on the one hand and *observation* (our old friend 'experience') on the other," [56] which is nothing other than what all "Aristotelian mechanics" continuously repeated. Guidobaldo Del Monte, for instance, stated that "it is very certain that practice and theory are always conjoined, and do not differ one from the other; and moreover I can say that demonstration taught me how to have experiences [in the sense of doing experiments]." [57] Theory and experience are thought of together, and theory, by means of hypothesis, can be an initial guide for the experiment which can validate or confute the theoretical presuppositions of the hypothesis itself. Through this fruitful dialogue, made possible also thanks to the mathematization of the world, mathematical theories were not only conceptual systems for making predictions, but also explanations, of course not of the essences of things (what Wootton calls the "why"), but at least of some of their properties, in the partial equivalence of the mathematical *factum* with the things created by God. This kind of mathematical knowledge is not in contrast to the Aristotelian *scientia*, as Wootton seems to suggest,[58] but rather mathematicians like Pietro Catena stated that they were compatible and constituted different standpoints on the same knowledge. An explanation, even if quantitative and not qualitative, of the *how* is always an explanation of a thing.

The question at stake here is not the break between the old Aristotelian conception, which should have explained the *why*, and the new scientific conception, which explained only the *how*, as Wootton asserts, because Aristotelians themselves had already exploited this distinction. Indeed, it is not true that the *how* does not provide causal explanations, rather, knowledge of the *how* explains how the fact is a *factum*, that is how a thing happens or is generated, in quite a different way from the explanation of the *why*, which concerns the essence. The central problem is rather why the explanation of the *how* superseded that of the *why*. It became more important because by means of the knowledge of the *how* ex-

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[54] N. Tartaglia, *Euclide megarense philosopho: solo introduttore delle scientie mathematice, diligentemente reassettato, et alla integrità ridotto*, Venice, Ruffinelli, 1543, p. 3v.

[55] N. Tartaglia, *Quesiti, et inventioni diverse*, Venice, Bescarini, 1554, p. 77v. Cf. A. De Pace, *Le matematiche e il mondo*, cit., pp. 187-260.

[56] W, 394.

[57] A. Favaro, *Due lettere inedite di Guidobaldo del Monte a Giacomo Contarini*, «Atti dell'Istituto Veneto di Scienze, Lettere, e Arti», 59, 1899-1900, p. 307.

[58] W, 393.

amined by the mathematics and mechanics, human beings could control nature, while with the mere contemplation of the essence supported by Platonics this was not possible.

3. Vulgarizing Knowledge and Linguistic Concerns

Wootton emphasizes that the strict connection between the fact and the experiment is a necessary but not sufficient condition for the instatement of modern science. There are two other essential conditions so that a knowledge can properly be called scientific: 1) the possibility of its communication; 2) the existence of community capable of understanding it. Wootton makes no secret of taking Robert K. Merton and Elizabeth L. Eisenstein's theses to the extreme. Merton's central claim is that scientific knowledge is always a public knowledge, because only publicity allows to question, test and dispute all the new information coming from all over the world.[59] Eisenstein's thesis, on the other hand, states that the printing press is what makes this publicity possible. Printed books, full of reliable and identical illustrations, improved access to information, making it easier "to establish and refute facts" and to replicate experiments.[60]

Wootton's claim is even stronger, however. What made the Scientific Revolution possible was the printing press because (1) it "turned private information into public knowledge, private experience into communal experience" and because (2) it constituted the transcendental condition of the fact. There could be no fact, or at least no fact could be established without a public statement of its existence. Wootton does not aim to diminish the achievements of those who make discoveries but never make them public,[61] rather he establishes that a knowledge, in order to be such, must be shared, otherwise it cannot lead to a progress,[62] not even in the restricted community where it is meant to be received. At the same time, without a community, no public knowledge can be tested or refuted, thus no experiment is possible. Scientific community and publicity of knowledge represent at the same time the conditions for the new science and its main features.

The public character of knowledge thus became a value, its secrecy a disvalue. In order to explain how the public character of knowledge impacts on science, Wootton highlights the discontinuity between alchemy and chemistry, which the scholarship is apt to view as a prosecution from the latter to the former. According to Wootton, no continuity is possible because the manner of understanding knowledge is so different. Even if both can be considered experimental sciences, the alchemic art "pursued a secret learning, convinced that only a few are fit to

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59 W, 96.

60 W, 282.

61 W, 96.

62 W, 340.

have knowledge of divine secrets," while chemistry was a modern science because it made knowledge public and had a community capable of testing experiments. Therefore, it is not the experiment to distinguish the old from the new science, but the publicity of knowledge and the existence of a community.[63]

It is the desire to make knowledge public to the greatest number of people and to create and expand the community that led to the adoption of new terms for explaining new things and the instatement of the vernacular languages in science. Hence we are back to Wootton's main thesis, which focuses on language. What is missing in his reconstruction is not only a clear demarcation between the history of terms and the history of concepts, but a reflection on language itself. Language is a starting point, but it is soon abandoned. In spite of a brief mention of William Gilbert and the use of new words to designate and to unveil new things, Wootton does not examine the relationship between new and the old languages, the progress of knowledge and the dissemination of scientific ideas. Nevertheless, it had to be a central element of his reconstruction if from language one has to find a revolution in mentality.

As Eduard Jan Dijksterhuis has suggested, with the continuous advancements of science and technology and the progressive accumulation of knowledge, new notions were born that intellectuals "preferred to express in the vernacular, which as a living language developed alongside the scientific research, rather than forcing the Latin to express thoughts that never were the subject of treatment." [64] Now, if it is from language that one recognizes revolutions, nothing was more revolutionary than the vulgarization of the ancient wisdom and the production of new knowledge in the vernacular so that the greatest number of people could have access to new ideas, make new hypotheses, establish new facts and replicate experiments. There are a number of statements of philosophers and scientists to the effect that new knowledge follows a new language and vice versa. For instance the Aristotelian Alessandro Piccolomini was obsessed by the problem of using a living, vernacular language capable of changing with the progress of knowledge and knew that only by coining new words to designate new discoveries it was possible to contribute to the progress of knowledge, which, otherwise, would be inhibited.[65] The use of the vernacular made "accessible scientific works to all classes of population," "stimulating not only an interest in science, but also the mobilization of all the forces that contribute to progress." [66]

Wootton's perspective in looking at knowledge and science from a linguistic standpoint is thus fruitful. To look for perfection and completeness in a study like this is a futile exercise. The strength of a book does not depend exclusively on

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63 W, 360.

64 E. J. Dijksterhuis, *De Mechanisering van het Wereldbeeld*, Amsterdam, Amsterdam Academic Archive, 1998, p. 269.

65 A. Piccolomini, *La prima parte della filosofia naturale*, Rome, Valgrisi, 1551, p. 1b r-v.

66 E. J. Dijksterhuis, *De Mechanisering van het Wereldbeeld*, cit., p. 270.

this, but also, and perhaps above all, on what makes you think and how many new threads of research it opens up. Wootton's book accomplishes both these tasks, much to its credit. One can praise or disagree with his constructivist approach, one can glorify or denigrate his attacks on the relativist methodology, but the only thing one cannot do is ignore this original and seminal book, which sets a new tone in the discussion of the alleged "Scientific Revolution."

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