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Philosophies of Technology

Francis Bacon and his Contemporaries

Edited by

Claus Zittel, Gisela Engel, Romano Nanni,
and Nicole C. Karafyllis

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Sophie Weeks has recently completed her doctoral thesis on Francis Bacon's science of magic at the University of Leeds. She is currently a Junior Research Fellow at Homerton College, Cambridge where she is investigating Bacon's concept of the unity of the sciences. The resulting monograph will examine his notion that rules for the government of human behaviour in political, social, and moral spheres should be grounded on a materialist natural philosophy. She is also working on seventeenth-century Baconian experimentalists (with C. Kenny).

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INTRODUCTION

Claus Zittel

The essays in the present volume attempt to historically reconstruct the various dependencies of philosophical and scientific knowledge of the material and technical culture of the Early Modern era and to draw systematic conclusions for the writing of Early Modern history of science. The volume's title – 'Philosophies of Technology' – however, contains several stumbling blocks. First of all, one could and should object to the anachronism, for the term 'technology' was first coined in 1777 in Johann Beckmann's *Anleitung zur Technologie, oder zur Kenntniß der Handwerke, Fabriken und Manufakturen, vornehmlich derer, die mit Landwirtschaft, Polizey und Cameralwissenschaften in nächster Verbindung stehen.*[1] The term 'technology' replaces older designations such as *historia artificalis* or *technica*, which referred to the theoretical discipline of mechanics as the study of motion, the mathematical study of motion, as well as the *artes mechanicae*, in short, the activities of skilled labour which were differentiated from the 'liberal arts'.[2] There was a particularly close connection between the *artes mechanicae* and the invention, construction, and use of machines in the Early Modern era. As practical arts, they increasingly undermined the old Aristotelian differentiation between artificial (i.e. produced by humans) and natural things.[3] The broad signification which the expression *ars* retained well into the 17th century, and which included everything artistic, is consequently limited at the end of the 18th century through the expression 'technology' to all that is connected, in a modern sense, with the applied sciences, practical mechanics, engineering (above all, machine construction) and a praxis-oriented methodology. Until then, technologies in this narrower sense had not formed their own sub-field in the culture but had

[1] Cf. Banse G. – Müller H.-P. (eds.), *Johann Beckmann und die Folgen. Erfindungen – Versuch der historischen, theoretischen und empirischen Annäherung an einen vielschichtigen Begriff* (Münster: 2001).

[2] Cf. Stöcklein A., *Leitbilder der Technik* (Munich: 1969), 31–35.

[3] Cf. for more specific information: Bennet J., "Mechanical Arts", in Park K. – Daston L. (eds.), *The Cambridge History of Science*, vol. 3: *Early Modern Science* (Cambridge: 2007), 673–695.

always been presented in connection with various scientific and skilled practices and an amalgamation of concepts from natural philosophy and cultural models.

The title of this volume also posits a strict relation between *philosophy* and technologies. According to current theories, however, this relation was marked by tension in the 17th century resulting from the frequently unsystematic and eclectic nature of 'technologies' which intensified into a conflict when practical knowledge was privileged above theoretical knowledge.[4]

The divisive transformation of humanist scholarly culture, the Scholastic school philosophy, as well as magic in the form of a philosophy of practice is always associated with the work of Francis Bacon. Bacon is, thus, an indispensable figure for the historical and systematic investigation of the complex interdependencies among science, technology, philosophy and society, advocating as he did a scientific ideal inspired by the concept of cooperation in service of the commonwealth and contributing to European sciences and philosophy by successfully arguing for and propagating experiment and controlled observation as fundamental to empirical research. His philosophy gave birth to the scientific dream of modernity that the advancement of society goes hand-in-hand with the unimpeded development of all technologies.

The examination of Bacon's experimental philosophy and its complex role in the formation of the Modern[5] is thus the starting point for a discussion of the guiding questions of this volume: Were developments in science and technology independent of one another – with technology on the one hand, philosophy and science on the other? Or in what sense do technology and technical development form part of what might be considered a shared European cultural heritage? What is the impact of technical models on the structuring of knowledge production in natural philosophy, natural history and the philosophy of history? How did technical models serve as explanatory models for the world at large? What was the level of technological development during Bacon's lifetime? What concrete form did the interconnection of technologies with other cultural practices take? Alongside the great heroes of scientific

[4] Gaukroger St., *Francis Bacon and the Transformation of Early-Modern Philosophy* (Cambridge: 2001), 14–18.

[5] Cf. on this: Engel G. – Karafyllis N. (eds.), *Technik in der Frühen Neuzeit – Schrittmacher der europäischen Moderne/Zeitsprünge. Forschungen zur Frühen Neuzeit*; vol. 8, no. 3/4 (Frankfurt am Main: 2004).

history, who were the influential actors? Do such simple differentiations between a culture of skilled-labour, of unplanned "doing", on the one hand, and a scientific culture, on the other, stand up to more precise historical analysis? How strongly was the development of theoretical knowledge in the Early Modern era connected with particular objects and instruments, thus on the material culture of the time?

Consequences for the historiography of the Early Modern era can also be indicated. The history of philosophy and the history of technology generally have very little to do with one another. On the one hand, the history of philosophy focuses primarily on the study of a few canonical texts and, thus, at the same time, almost always privileges an understanding of philosophy that suggests it is independent of cultural contexts and technological developments. Philosophy is understood as something 'written in books', and the role of instruments and technical innovations for the development of philosophical theories seldom comes into focus.[6] On the other hand, the history of technology is often characterized by tunnel vision, with its studies of local innovations or broad surveys which devote little attention to the philosophical and aesthetic[7] implications of technical phenomena. The more the history of technology opens itself to contemporary the newer history of science, the less likely it is to fall prey to this narrow perspective.[8]

At least since Shapin and Schaffer's pioneering study *Leviathan and the Air-Pump*,[9] the view in Early Modern histories of science has finally been accepted that, just as in the Ancient and Medieval eras, science and philosophy cannot be separated in the Early Modern period either. Medical doctors, physicists, and chemists in particular, as well as natural scientists employing an experiment approach, referred to themselves as philosophers. For Leibniz, Descartes, Bacon and Boyle,

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[6] In this regard, Biagioli M., *Galileo's Instruments of Credit. Telescopes, Images, Secrecy* (Chicago: 2006); Reeves E., *Galileo's Glassworks* (Harvard: 2008); Wilson C., *The Invisible World: Early Modern Philosophy and the Invention of the Microscope* (Princeton: 1995), among others, are exemplary models.

[7] Important exceptions are: Lefèvre W. (ed.), *Picturing Machines 1400–1700* (Cambridge, Mass.: 2004); Schramm H. – Schwarte L. – Lazardig J. (eds.), *Kunstkammer, Laboratorium, Bühne. Schauplätze des Wissens im 17. Jahrhundert* (Berlin: 2003); Schramm H. – Schwarte L. – Lazardig J. (eds.), *Instrumente in Kunst und Wissenschaft. Zur Architektonik kultureller Grenzen im 17. Jahrhundert* (Berlin: 2006); Holländer H. (ed.), *Erkenntnis, Erfindung, Konstruktion. Studien zur Bildgeschichte von Naturwissenschaften und Technik vom 16. bis zum 19. Jahrhundert* (Berlin: 2000).

[8] On this cf.: Golinski J., *Making Natural Knowledge* (Cambridge: 1998).

[9] Shapin S. – Schaffer St., *Leviathan and the Air-Pump* (Princeton: 1985).

the explanations of such natural phenomena as magnetism, rainbows, *horror vacui*, air pressure and gravity naturally fell within the realm of philosophy. The debate about experimental facts was simultaneously a debate about what could be considered a fact at all and thus constituted a theoretical conflict. This state of affairs, as Christoph Lüthy recently put it, should ultimately *force historians of philosophy to become historians of science and vice versa*.[10]

Nevertheless, as Lüthy has shown in numerous prominent examples, the focus on philosophical texts employing systematic argumentation has remained defining for contemporary historiography, despite the general awareness of the broad understanding of philosophy in the Early Modern era.[11] Such is not the case, however, for the new, expansive *Cambridge History of Early Modern Science*,[12] which includes an exemplary broad spectrum of topics in natural philosophy, science, technology, scientific objects, instruments and art. The essays in the *Cambridge History* are dedicated to an in-depth exploration of the epistemic core of technical developments in their socio-cultural contexts. Typically, however, it does not present itself as a 'History of Early Modern Philosophy'.

To offer a more concrete explanation, I would like to turn to Descartes. In rule ten of his so called '*Regulae*', in his first draft of a new method of philosophy, René Descartes explains how to make use of a new kind of practical sagacity, based upon acquired skill, experience, subtle wit and cunning. This sagacity should make the ingenium capable of detecting patterns of organization in unknown facts and putting these new patterns in relation to other forms of organisation. But how do you learn to use such sagacity, particularly for someone lacking a strong natural inclination to independent research? According to rule 10, one should undergo mental training, running through in their mind various organizational forms:

> In order to sharpen the intelligence, it should be exercised in searching for things that have already been discovered by others and it should review methodically even the most trivial results of human skill, especially those that deploy or presuppose order.

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[10] Lüthy Chr., "What to Do with Seventeenth-Century Natural Philosophy? A Taxonomic Problem", *Perspectives on Science* 8 (2000), 164–195, here: 166.

[11] Positive counterexamples are: Rossi P., *Philosophy, Technology, and the Arts in the Early Modern Era* (New York: 1970); Pérez-Ramos A., *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition* (Oxford: 1988).

[12] Park K. – Daston L. (eds.), *The Cambridge History of Science*, vol. 3: *Early Modern Science* (Cambridge: 2007).

> But since every intelligence is not disposed by nature to investigate things by its own efforts, this proposition teaches that we should not initially undertake the most difficult and arduous things, but should first tackle some very simple and trivial arts, and primarily those in which order is most evident – such as those of artisans who weave tapestries and carpets, or of women who do needlepoint or weave threads of various textures in infinitely many ways [...] It is surprising how much all these things exercise one's intelligence.[13]

Thinking, weaving, knitting: if the eye is trained in recognising patterns, the ingenium can be helped along in the discovery of structural analogies between apparently different phenomena.

Descartes' appeal to the carpet weavers[14] is striking but represents no exception in the early 17th century. However, I chose the Cartesian example in order to show that even Descartes, as the supposed opponent of Baconian sciences, was quite certain about the necessity of sustaining theoretical knowledge through learned experience, maker's knowledge, and observations. Descartes also followed the Baconian program of learned experience, that new knowledge should be discovered by ingenious adaptation of existing knowledge rather than by formal inference from fundamental principles (*De Augmentis*).

All forms of available knowledge, hence no longer chiefly that presented in books, should become a resource for the generation of new knowledge. To understand this knowledge in its diversity and to continually expand it with new research can only take place, according to Bacon, through a collective effort in the gathering of experiences of all kinds, in examining and sifting through knowledge, and in well-planned teamwork for generations beyond the boundaries of professional constraint. Philosophy and every-day technical practices prove to be bound together. On the basis of the mechanical arts, 17th-century natural philosophy develops a correspondingly technological (and particularly with Bacon and his successors a masculine ruling) metaphorical language which would long dominate the representations of humans, mind and nature.[15] In the face of such strong ties between

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[13] Descartes, *Regulae*, in: *Œuvres de Descartes* [= AT], ed. Ch. Adam – P. Tannery, 11 vols. (Paris: 2nd ed.: 1971–1975), vol. XI 404.

[14] Cf. Nanni R., "Machinae ad maiestate imperii e macchine della manifattura tessile", in: Engel G. – Karafyllis N. (eds.), *Technik in der Frühen Neuzeit – Schrittmacher der Europäischen Moderne* (Frankfurt am Main: 2004), 409–441.

[15] Cf. Scholz S., "The Mirror and the Womb: Conceptions of the Mind in Bacon's Discourse of the Natural Sciences", in *Women. A Cultural Review* 3/2 (1992), 159–166.

theoretical and practical knowledge, it clearly makes little sense to think in terms of a division between 'high science', which aims at truth, and 'low science', which aims at usefulness.

It is, moreover, hardly possible to present a unified paradigm of an interpretive example for all the various technological developments, including their interconnections with philosophy and science. Just as the supposed scientific elite utilise the arsenal of practice, engineers and practitioners attempt to ennoble their activities by anchoring them in the high discourse of their era and to bolster their discoveries and constructions through philosophical or theological considerations.

The Cartesian example also makes it clear, more over, as is always emphasised in Early Modern histories of science, that this interconnection served not only to drive the scientific revolution of the 17th century. Parallel to this, in the space of only a few decades, six crucial instruments were invented: the telescope, the microscope, the air pump, the pendulum clock, the thermometer and the barometer. Naturally, they made it possible to carry-out experiments and make measurements which had previously been unthinkable. Nevertheless, we cannot afford to limit our historical focus to these few inventions. A wealth of other inventions and technologies employed and experimented with in the philosophical communities inspired by Leonardo Da Vinci and Bacon also provides practical knowledge relevant to the emergence of so-called mechanical philosophy.

While Descartes' 1626 proposition shows that the knowledge employed by weavers gained new respect as an intellectual resource, lens makers, machine builders, musical instrument makers, milk maids producing butter and sailors also became important sources for him. Bacon and William Gilbert not only made new discoveries but also discovered new methods in the reports of sailors and pilots and navigators. In their attempt to establish a new experimental science, Fabricius da Aquapendente studied mills, Paracelsus referred to woodworkers, while Bacon looked to sailors and others. Diviners, physicians, civil and architectural engineers, pyrotechnicians, artillerists, oven builders, specialists in hydraulics, shipbuilders, potters and design techniques, workshops, alchemical laboratories, military technologies[16] (and so

[16] Cf., Parker G., *The Military Revolution. Military Innovation and the rise of the West, 1500–1800* (Cambridge: 1988). Up to now useful is, Jaehns M., *Geschichte der Kriegswissenschaften, vornehmlich in Deutschland*, 3 vols. (Munich: 1889–1891).

on) can all be considered furnishers and sources of new methods and models for Early Modern cultures of knowledge.[17]

With the broadening of the scope of recent histories of science to include various technologies – and by integrating practical knowledge and theoretical contexts – an image of knowledge has emerged of a social environment in which philosophers and inventors of machines relied upon communication, collaboration, exchanges of experimental and observational reports, and patronage. New financial risks and strategies, new tactics for disseminating knowledge claims and secretive practices emerged, and new relationships concerning the changing role and significance of practical knowledge and technologies with respect to scientific theories and the traditional metaphysical foundations of knowledge also require further examination. Nevertheless, we should keep in mind that there may always be a difference between the ideals of knowledge based on experience and the practice of experimental research or technological invention, which are all too often concealed in later historical reconstructions of the Early Modern period.

The sphere of that which qualifies as 'technological' is ever expanding. Reference is made not only to the classic texts on technology and the history of machines, but the history of technology is now understood as an element of cultural history, alongside philosophy and the arts, as having contributed to the mobilisation of metaphors and the development of ways of thinking. Technical metaphors, technological models and inventions can thus be found not only in machine books of the Early Modern era[18] but also, for example, in texts like Descartes' *Discours de la méthode*, in art treatises and literary works.

It is in this context – however briefly sketched – that the essays in the present volume, *Philosophies of Technology*, intersect. The book is organised strictly along interdisciplinary lines. Whereby "interdisciplinarity" is not achieved merely by collecting essays from various disciplines into a single volume; rather, the problematic addressed in each individual essay necessitates the crossing of traditional disciplinary boundaries, reflecting a genuinely interdisciplinary perspective on its subject.

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[17] On this, Cf.: Lefèvre W. – Renn J. – Schoepflin U. (eds.), *The Power of Images in Early Modern Science* (Basel: 2003).

[18] The broadest overview of the machine books of the Early Modern era are in: Olschki L., *Die Literatur der Technik und der angewandten Wissenschaften vom Mittelalter bis zur Renaissance*, 3 vols. (Heidelberg: 1919). A newer account can be found in: Popplow M., *Neu, nützlich und erfindungsreich. Die Idealisierung von Technik in der frühen Neuzeit* (Münster-New York: 1998).

Instead of summarising the arguments of each contribution, my brief discussion of the essays collected here groups them thematically, touching on its key problematic. Despite the orientation of the collection on the history of science, only three of the essays come from the specialised discipline (Epple, Weeks, Borelli), while the rest come from such disciplines as philosophy, English, history of technology, legal history and art history.

The examination of Bacon's understanding of technology naturally constitutes a focus of this volume. The limited research thus far on the concrete relation of Bacon to the technical developments of his time has tended to point in sweeping gestures to Bacon's call for the replacement of scholarly culture with scientific culture, an appeal, so the argument goes, based on the juxtaposition of the new, progressive mechanical arts, on the one hand, and tradition-bound philosophy, on the other. In his standard work on the history of technology, Paolo Rossi formulates the still generally accepted assessment: 'Virtually the whole work of Francis Bacon addressed itself to the task of replacing a culture of rhetoric-literary type by a culture of a technico-scientific type.'[19]

This depiction is now being revised from various perspectives: Romano Nanni demonstrates that important technological changes proclaimed by Bacon to be innovations had, in fact, already been achieved much earlier; Sophie Weeks investigates the role of magic and its experimental practices, postulating that Bacon's understanding of mechanics does not have to be seen in strict opposition to magic, as Bacon himself sometimes suggested, but rather represents a transformation of magical practices. Luisa Dolza argues that through a stronger embedding in the culture of practitioners in England and on the continent, particularly in the so-called 'Machine Theatre', it was moreover clear that theology and the new technology were not oppositional, as the often theological and philosophical foundations of machine books and technical inventions illustrates. Dana Jalobeanu's examination of the discrepancies and connections between Bacon's scientific utopia in *New Atlantis* and the collection of experiments *Sylva Sylvarum*, two essays which were published together in a single volume, offers new insights into Bacon's particular rhetorical and fictional strategies. The

[19] Rossi P., *Philosophy, Technology, and the Arts in the Early Modern Era* (New York: 1970) 80.

dissemination of new technical utopias, as she suggests, by no means stands in opposition to the rhetorical tradition but rather feeds on it. On the other hand, Jürgen Klein interrogates the potential model of artists' workshops as a factor in the development of Bacon's philosophy, especially in light of the fact that the young Bacon had very likely attended lectures from Bernard Palissy in Paris and allegedly made a secret tribute to him in his early text, *Redargutio Philosopharum*.

Andrew Borlik maintains that Cornelis Drebbel is personified in the figure of the inventor of the barometer in *New Atlantis*. This essay marks the starting point for a second group of essays concerned with the history of instruments and their role in the formation of philosophical theories. Arianna Borelli focuses in particular on the history of barometers, in the wake of whose invention it was suddenly possible to make visible previously invisible movements of air. As can be shown in detail, this invention influenced in various ways the development of philosophical methodology in Giambattista della Porta, Francis Bacon, René Descartes and Robert Fludd. Along with Cornelis Drebbel, practitioners such as Salomon de Caus, Jacques Besson or Palissy, influenced the conceptual world of 17th-century natural philosophers with their mechanical inventions, even to the point of creating metaphors. Experimentation with musical instruments also played an important role in the development and transformation of early modern knowledge systems. Benjamin Wardhaugh analyses the relation between specific material objects, such as music instruments, and science in his essay, examining the way in which various uses of 'harmony' can illuminate mechanical, mathematical and experimental approaches to sound and music in Early Modern natural philosophy.

Another group of texts looks at technical metaphors, paying particular attention to the explanatory function of technical models in Bacon (Sophie Weeks), Harvey (Jarmo Pulkkinen) and Descartes (Andrés Vaccari, Claus Zittel). The special relevance of hydraulic and hydrodynamic models crystallizes here, for example, in the description of the human body. Hydrodynamic processes, in particular, can hardly, if at all, be reconciled with a rigid, machine-like understanding of mechanics. This leads to the conclusion that later conceptions of mechanics are much too narrow for that of the 17th century in order to conceptually grasp all that was understood at the time as mechanical processes; thus, for example, that historiographical models of the body as a machine or the world as a clock represent simplified projections back onto the era. This same phenomenon helps explain, as Staffan Müller-Wille points out in the field of botany, how the impact of Bacon's scientific reform, including its theological implications, was largely ignored in later natural history.

In the 18th century, in other areas of natural philosophy the narrow understanding of mechanics dominated and some scientists, in express opposition, designed a 'sentimental hydraulics' based, as Thomas Brandstetter argues, on a firm rejection of traditional mechanistic constructions. There was a shared conviction that gearwheels, levers and other classical machine elements could not be added to the economy of nature. For this reason, numerous inventors struggled to design instruments which functioned without mechanical parts. With hydraulic and pneumatic constructions, the hidden forces of nature were to be harnessed and the disadvantages of conventional machines simultaneously avoided. Precisely because they could be so readily introduced into the natural economy such constructions also promised comprehensive political and social reforms.

Brandstetter's essay on hydraulics and essays by Moritz Epple and Daniel Damler are dedicated to another important area, the cultural dimension of spectacular hydraulic constructions such as the *Artifico* in Toledo, constructed by Juanela Turriano (Damler), which at the time was admired as a wonder of the world by Cervantes, Quevedo, and Lope de Vega. This perspective allows us to scrutinize, in turn, the conventional image of the Catholic Spanish monarchy as an enemy of science.

By analyzing the plans for the artificial fountains of Versailles and those of Sanssouci, Moritz Epple demonstrates how and to which degree in the 18th century the water lifting facilities and fountains provide the metaphors and the heuristic tools for the hydrodynamicists' theory. Hydraulic technology plays the role of a mediating field. Even though there was a gap between mathematical hydrodynamics and hydrotechnological practice in the 18th century, both mathematicians and engineers shared the utopian dream of mathematized hydrotechnology. Against this background Epple dicusses the complex interaction between hydrodynamics and hydrotechnology and argues that the scientific key concept of hydrodynamic pressure emerged from technically-oriented consideration.

Bertold Heinecke and Pablo Schneider demonstrate that Bacon's philosophy of technology exerted a powerful influence on literature and the arts. Heinecke delves into the close relationship between literature, technical inventions and experimental natural philosophy with regard to the influence of Bacon on German poet Georg Philipp Harsdörffer. Harsdörffer developed a method of playful combination that productively merged technical and poetic invention. Schneider shows how Bacon's leitmotif of the call for scientific explanation and the unlimited nature of science, 'the open horizon', altered representations of power in English and French architecture.

All of these essays in this volume reflect the close interaction between technical models and knowledge production in natural philosophy, natural history and epistemology. It becomes clear that the technological developments of the Early Modern era cannot be adequately depicted in the form of a pure history of technology but rather only as part of a broader, cultural history of the sciences.

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