ROBERT ARNĂUTU

Central European University, Department of Philosophy
Email: robertarnautu1979@yahoo.co.uk

THE RENAISSANCE CONCEPTION REGARDING TECHNOLOGY

Abstract: The Renaissance creates a clear-cut distinction between mechanical arts, which will come to be considered applied science by Bacon and Descartes, and fine arts. Dealing with the Renaissance approach to technology, this paper will focus, on the one hand, on those domains that combine theoretical and practical skills in order to create artifacts or to transform materials, and, on the other hand, with authors who debate the status of technological practices and knowledge. Thus, we will look at the developments and arguments regarding mechanics, alchemy, natural magic, mining and metallurgy, and at authors such as Georgius Agricola, Paracelsus, Masilio Ficino, Nicholas of Cusa, and Galileo Galilei. The aim is to reconstruct the arguments regarding technology that challenged the established Scholastic-Aristotelian framework and made possible the Modern approaches.

Key words: Renaissance, technology, mechanical arts

Journal for Communication and Culture 1, no. 2 (Winter 2011): 141-161

E-ISSN & ISSN-L: 2247-4404
www.jcc.icc.org.ro • *contact@icc.org.ro*

The Renaissance is usually considered to be the period roughly between 1450 and 1620, although its origins are traced back to Petrarch around 1350 in Italy. This is a very tumultuous period with various preoccupations and solutions to old and new problems. The scientific and philosophical starting point of the Renaissance are the works of three Ancient authors, Aristotle, Galen and Ptolemy, completed by Arabic and Middle Age commentaries on these authors[1]. Based on this framework, the Renaissance thinkers and practitioners of mechanical arts create an autonomous domain that later will be recognized as technology. The importance of the Renaissance rests in the fact that, as Sawday[2] claims, "many of our complex and contradictory attitudes towards our own technologies were [...] first shaped in the period of the European Renaissance."

In the twelfth century in Latin Europe began an important translation movement from Arab and Greek into Latin. The main purpose was to translate scientific and philosophical books. In mid-twelfth century James of Venice translated the entire logical corpus of Aristotle. In the same time, Gerard of Cremona translated into Latin Aristotle's *Posterior Analytics*, *Physics*, *On the Heavens*, *On the Universe*[3], *On Generation and Corruption*, and *Meteorology*. Along with these works, the translators of the twelfth century translated also the Arabic commentaries on Aristotle. In mid-thirteenth century, William of Moerbeke translated the entire Aristotelian Corpus and his edition will become the standard translation for many years. Having such a great number of manuscripts as well as a coherent system, Aristotle became the official philosopher of the Catholic Church. In addition, the conciliation between Aristotle's philosophy and Christianity undertook by Thomas Aquinas helped Aristotle a lot in becoming the supreme authority in all domains of human knowledge. His doctrine is the doctrine taught in Schools all over Europe during the entire Renaissance.[4] Nevertheless, his teachings are critically approached and not followed blindly. After the condemnation in 1277 of 219 propositions, many of them Aristotelian, rejected as "errors" by the Church, the works of the Stagirite are more freely interpreted and other scientific options are investigated.

Renaissance thinkers will bring arguments against the limitations of technology set up by Scholastic doctrine and Aristotelian tradition. During the Renaissance the Aristotelian term *techne* is translated as *ars* and a clear-cut distinction between liberal arts and mechanical arts (a phrase I will use as synonymous with "technology") is imposed. Despite this distinction, both liberal and mechanical arts are part of the larger genus called *ars*; as such their essential characteristics are common. The term "mechanical arts" does not refer only to mechanics but to every production of useful things. During the Renaissance, there is no systematic approach to technology but the various arguments pertaining to the value of mechanical arts prepare the seventeenth century philosophical approach to technology.

As I try to show that during the Renaissance the conceptions of technology begin to change I should give an overview of the actors involved in this change. Their mutual debates and mixing of disciplines prepare the field for the inauguration of mechanical philosophy and a proper theoretical evaluation of technology. Edgar Zilsel in his 1942 article "The Sociological Roots of Science" proposed the idea, which is fundamental for this paper, that the interaction of artisans and scholars in the Renaissance is the starting point for the modern science and for the modern conception of technology:

> In the period from 1300 to 1600 three strata of intellectual activity must be distinguished: university scholars, humanists, and artisans. Both university scholars and humanists were rationally trained. [...] Both professors and humanistic literati distinguished liberal from mechanical arts and despised manual labor, experimentation, and dissection. Craftsmen were the pioneers of causal thinking in this period. [...] The craftsmen, however, lacked methodical intellectual training. Thus the two components of the scientific method were separated by the social barrier: logical training was reserved for upper-class scholars; experimentation, causal interest, and quantitative method were left to more or less plebeian artisans. Science was born when, with the progress of technology, the experimental method eventually overcame the social prejudice against manual labor and was adopted by rationally trained scholars. This was accomplished about 1600 (Gilbert, Galileo, Bacon). [5]

The university scholars were trained for the first six years of their studies in the faculty of arts where they would learn mainly logic and philosophy based on Aristotle's works and their commentaries. The arts referred to in the name of the faculty comprise the seven liberal arts (logic, grammar, rhetoric, arithmetic, geometry, astronomy, and music theory) which had to be known by the student in order to obtain a Bachelor Degree. Being a Bachelor of Arts, the student could pursue his studies in law, medicine or theology. Theology studies were the mix between Christian theology, Aristotelian metaphysics and natural philosophy. The theologians of the universities were the principal adversaries of humanists and learned artisans. They represented the Knowledge. Their writings were strictly textual, arranged in the scholastic form either as commentary or as debates of metaphysical questions.

The humanists were mainly scholars and writers that oppose the scholastic methods, scholastic Latin, and the scholastic ideal of man. They tried to revive the ancient traditions and to create a moral citizen taking as model classical antiquity. They rediscovered ancient texts, alternative philosophies to mainstream Aristotle, applied philological methods to texts, dealt with alchemy, mystical and hermetic philosophy. They emphasized practical wisdom. Their writings, again strictly textual, emphasized eloquence, beautiful style and the moral and practical development of individuals.

Finally, there were the learned artisans who were hired by the nobility to work in mechanical and fine arts and who began to write books in order to disseminate their know-how. The men in power at that time patronize all arts, either out of necessity, e.g. mining for gold or gunnery for power, or out of the need to show off their power, e.g. architecture or water-mechanisms. Their patronage leads to inventions, development and dissemination of technical knowledge. The books of artisans were rich in accurate drawings of mechanisms, accompanied by little text, which in fact consisted of recipes and descriptions of the construction and working of those mechanisms. "According to some experts' estimation, for the period 1400–1700 alone, one has to reckon with five to ten thousand drawings of machines and machine parts"[6]. The world of technicians was very different from that of scholars and humanists. While the latter were studying Latin and philosophy for many years, "workshop apprenticeships usually began at an early age (8–14 years), often after an elementary education involving vernacular reading, writing, and arithmetic"[7].

Mechanics

One of the main domains that promote the development of the early modern philosophy of technology is mechanics. The creation of mechanisms, a widespread activity during Renaissance, became a field of interest for scholars and the subject of various books in the period. At the beginning of the Renaissance, some important ancient works dealing with mechanisms are translated into Latin, and Renaissance authors begin to write their own treatises on the subject. The most influential ancient work is *Mechanics* (*Mhkanixe*), a book wrongly attributed to Aristotle. The fact that it was attributed to Aristotle raised its value in the eyes of a Renaissance man. The book was considered unique amongst Aristotle's work because it focuses on simple machines, describing pulleys, gears, levers, and other devices that produce mechanical advantage and also because it mixes physics and mathematics in treating mechanical problems.

Other authors who have written about mechanical devices and whose texts were discovered during the Renaissance and deeply influenced it were Vitruvius, Hero of Alexandria, Archimedes and Pappus. The combined works of Aristotle and Hellenistic authors form the basis for the Renaissance development of both technology and a philosophical conception of technology.[8]

The Renaissance artisans begin to write their own books on various mechanisms, such as mining and military mechanisms, waterworks and mechanical marvels.[9] They improve on ancient mechanisms and help disseminate technological know-how across Europe. Few of those books, the most renowned exception being the *Büchsenmeisterbuch*, are really intended for practitioners. They were too expensive, too large, and in fact, the designs are hard if not impossible to be reproduced at scale.

One of the important issues for the Early Modern philosophy of technology is the relation between mechanics and nature. This relation is formulated the answer to two main questions, one regarding the autonomy of mechanics and the other regarding the workings of nature. The first question: Is mechanics an autonomous domain or is it just an imitation and perfection of nature? The second question: To what extent are the mechanisms present in natural phenomena? The traditional view is that mechanics cannot create new things and that the works of nature, even if they exhibit some similitude with mechanical devices, are of different ontological category.

The relation between technology and nature is complicated by the fact that during Renaissance the modern dichotomy natural-unnatural is differently conceived. Events and objects are divided in five big categories (natural, supernatural, preternatural, artificial and unnatural), nature being what *usually* and *normally* happens without man and God's intervention:

> The early modern period instead utilized a variety of categories defined vis-a-vis the natural. The *supernatural* was a category largely created by Thomas Aquinas (1225–1274) in the thirteenth century. He viewed miracles – supernatural events – as God's intervention in the natural order and therefore above that order. A second category, '*preternatural*', described events that were highly unusual, "beyond nature," but not supernatural. Examples include monstrous births, bizarre weather, the occult powers of plants and minerals, and other deviations from ordinary natural events. A third category, the *artificial*, comprised objects fabricated by humans that could imitate nature but could never become part of the natural world. Finally, the *unnatural* was a moral category used to describe acts, such as patricide and bestiality, which transgressed the natural order ordained by God.[10]

Therefore, nature is limited to what is normally ordered without man or God's intervention and strange natural phenomena are excluded from the realm of nature. If the artificial is to imitate nature but not the preternatural then mechanics cannot attempt to satisfy natural standards based only on similar structural features. A basic ingredient, which only the natural things have, is missing and it cannot be created by man.

The artisans only imitate and can at best bring improvements to natural things, i.e. to what is usually present in nature. The highest perfection to be attained in mechanical arts is innovation, improving tools in accordance with nature, but never invention, i.e., creating new things with no natural counterpart.

One argument for the inventiveness involved in technology, and therefore its autonomy from nature comes from Nicholas of Cusa. He writes in 1450 three dialogues known as *Idiota* after the main character, a layman in the market-place. Nicholas of Cusa wanted to show that the knowledge extracted from experience by the layman is superior to the mediated knowledge of scholars. This is a recurrent humanistic idea especially in literal texts such as those of Rabelais and Moliere that ridicules the unintelligible Latin and the much too complicated explanations of Scholasticism. Nicholas of Cusa tries to extract a certain province of art from the realm of imitation, a conception that perpetuates from Plato and Aristotle on. His argument was that there are products of human artistry that have no eternal archetypes and they transcend created nature. These products cannot therefore be products of imitation but human inventions:

> Having taken a spoon in hand, the Layman [artisan] said: "A spoon has no other exemplar except our mind's idea [of the spoon]. For although a sculptor or a painter borrows exemplars from the things that he is attempting to depict, nevertheless I (who bring forth spoons from wood and bring forth dishes and jars from clay) do not [do so]. For in my [work] I do not imitate the visible form of any natural object, for such forms of spoons, dishes, and jars are perfected by human artistry alone. So my artistry involves the perfecting, rather than the imitating, of created visible forms, and in this respect it is more similar to the Infinite Art".[11]

There is a paradigmatic difference between Aristotle and Nicholas of Cusa. Aristotle in *Physics* (199a) also accepts the idea that there are some artifacts, creations of human technology that do not resemble any natural object, for example houses. Nevertheless, for Aristotle houses are a kind of imitation either because nature would have created houses if it were perfect or because humans possess the instinct to create shelters in the same way birds create nests. In the case of Nicholas of Cusa the story is totally different. In no potentiality of nature the forms of human artifacts pre-exist. The technician creates *ex nihilo* forms and shapes that serve human needs. Nicholas of Cusa defends both human inventiveness and the positive value of utility against Aristotle's dogma.

The autonomy goes even further in late Renaissance such that mechanics is thought to create a different realm altogether, a realm that competes and even surpasses nature. Mechanics is even thought to be so powerful that it can cheat nature. Such a view on technology should grant that mechanics is a totally autonomous domain that cannot be reduced to imitation and that different rules apply to mechanics that overcome the laws of nature such that the latter can be "cheated".

A different perspective on the relation between mechanics and nature is taken by the professors of mathematics in Padua. Professors of mathematics, such as Galileo, used mechanics and pseudo-Aristotle's *Mechanics* in their teachings aiming at discovering the natural laws by manipulating mechanisms.

Galileo Galilei shows in his writings that mechanical laws apply in nature and that nature is to a great extent mechanical. This was the greatest impediment for technology and a point of metaphysical disputations and arguments. The matter could not be solved empirically. For Scholastics, there is a set of laws that works in nature and another that works in the experiments and artifacts of mechanical arts. This argument, which was valid for the Scholastic-Aristotelian philosophy, is rejected more than once during the sixteenth century on the basis that "certain man-made artifacts like mechanical clocks and birds had (even as Nature's own productions) that inner principle of motion which presumably acted as an identifying mark of the natural"[12]. Experiments, artifacts and nature obey one and the same law, therefore what ones find in experiment or by observing artifacts is the way everything, including nature, behaves.

Giuseppe Moletti, Galileo's predecessor as professor of mathematics at Padua, discusses the idea that the possibility of mechanics to imitate nature comes from the fact that in nature itself mechanics is at work. The solution offered by Molleti is that the nature obeys mechanical laws and mechanics is perfectly natural. "In general the art of mechanics is found everywhere in nature, meaning that mechanics operates on fully natural principles"[13].

Galileo Galilei promotes the idea that mechanics could bring us knowledge about nature and that the technology is an important field for philosophy to research. In the beginning of the *Two New Sciences* Salviati says: "The constant activity which you Venetians display in your famous arsenal suggests to the studious mind a large field of investigation, especially that part of the work which involves mechanics; for in this department all types of instruments and machines are being constructed by many artisans"[14]. The importance of this acknowledgment, that mechanics is a proper subject of philosophy, is that it inaugurates a completely new ideology of knowledge. This phrase represents the end of Aristotelian classification of knowledge.

That the everyday practice of mechanics should be the subject of philosophy is perhaps the most revolutionary statement in Galileo's famous work. Clearly, something had to have raised the intellectual standing of mechanics for Galileo to feel that the philosophical audience to whom he was addressing the *Two New Sciences* would continue reading past those first lines.[15]

Galileo does not identify the laws of nature with the laws of mechanics but he maintains that the two domains have the same limits and nature, whatever it does, should obey mechanical laws.

> Finally, we may say that, for every machine and structure, whether artificial or natural, there is set a necessary limit beyond which neither art nor nature can pass; it is here understood, of course, that the material is the same and the proportion preserved.[16]

Be the artifact different from the natural structure, there are identical limits that should be obeyed. The natural world, even the human organism, must obey the physical laws of construction that apply to mechanisms. Also, these limitations work both ways such that mechanics cannot "cheat" nature. From the mechanical point of view, there is no more a separation between natural and artificial and nature can be known by observing the construction and working of mechanisms. Scientists as Galileo "challenged traditional Aristotelian categories by bringing together *techne* (manipulation of machines and instruments) and *episteme* (theoretical knowledge). Seventeenth-century Aristotelians countered the experimentalists with the argument that this combination was a category mistake involving the improper fusion of separate conceptual entities"[17].

Alchemy

Beside mechanics, another source of developments and arguments pertaining to technology are the experimental parts of occult sciences and various theoretical works on Renaissance crafts.

Alchemy is a mystical and experimental endeavor, the precursor of chemistry. A lot of natural philosophers during Renaissance deal with alchemy[18], and this section focuses on the experimental part of this "art". The aim of alchemy is to create "medicines" that "heal" metals, bodies and souls, i.e. to create substances that transform ordinary metals into noble metals, that heal body illnesses and that perfect the soul.[19] Alchemy is developed out of two sources: the recipe literature of Middle Age monasteries, that provide recipes on metalwork and how to make glass, pigments, panels, etc., and the Arabic texts on alchemy in which a coherent theory of metals, as composed of two basic components (sulfur and mercury), was developed.[20] The most important synthesis and the most influential alchemical text is *Summa perfectionis magisterii* written probably by Paul of Taranto around 1280 and attributed to Gerber, Jābir ibn Hayyān, an Arab polymath from the 8th century. The Arabic theory of mercury-sulfur is combined in this book with Aristotle's *minima naturalia* theory[21], the result being a working theory which can explain the properties of minerals and their transformations in laboratory. Masilio Ficino and other humanists such as Cornelius Agrippa, Paracelsus, and Giordano Bruno favored alchemy in its most scientific form based on Arab books and their own chemical experiments and even thought to promote alchemy as a university discipline:

> Alchemy failed to find acceptance within the curricula of the medieval universities, and it came under increasing attack with a backlash that had set in by the end of the thirteenth century. The discipline was not incorporated into university curricula in part because it included operational, workshop processes with connections to craft traditions such as dyeing and metallurgy, which were incompatible with the logical orientation of university scholasticism.[22]

Also, because the claim that the alchemists can create gold, a practice that would destabilize a gold-based economy, Pope John XXII issued a bull against alchemical counterfeiting. In fact, it was this rejection from the university and the Church that transforms alchemy from an honorable proto-science into the late abracadabraic movement. Because of the papal bull as well as for preserving the secrecy of their recipes alchemy authors begin to use "cover names" for substances:

> It is true that the Latin alchemists acquired the Arabic (and ultimately Greek) practice of substituting the planetary names for the metals, so that gold became sol, silver luna, copper venus, iron mars, tin jupiter, lead saturn, and quicksilver mercury. Yet this simple substitution code was only one element in a complex and variant set of Decknamen or "cover names" alchemists used. In the rich alchemical glossaries of the Middle Ages, quicksilver's planetary designation had to compete with such names as "the fleeting," "the runaway," "the fugitive slave," "the cloud," "the lightning," "the heavy water," "the spirit," "the fluid," and "water of life," to name but a few.[23]

Behind these very colorful metaphors the practitioners of alchemy were making real chemical experiments in their laboratories. There are three important aspects in their work that contribute to a philosophical conception of technology: the use of experiments reproduced over and over again, the creation of new substances that do not exist naturally and the use of scientific instruments.

One of the alchemists' main purposes is to create gold. In fact they try to obtain the right soil in which gold could vegetate and germinate. The metals are, for Renaissance and Early Modern non-mechanical thinkers, natural elements that, in the same way as plants, grow into the soil. Therefore, the gold should be obtained out of gold seeds, i.e. probably the gold itself, implanted in the proper soil. Lawrence Principe reproduced the experiments described in alchemy books and obtained such a germination of gold:

> After a fairly lengthy process involving various materials and numerous distillations, I obtained an 'animated' Mercury, which was supposedly the necessary 'mineral water' that mercurialists required for the 'moistening of the seed of gold'. […] After several days of heating, the metallic lump took on a completely new appearance [that] some today might call this a dendritic fractal but I think that most onlookers would refer to it first as a tree.[24]

The trust in the powers of technology comes from the belief that alchemy artfully combines the basic natural elements. The quality of artifacts is not a consequence of some supernatural powers that the alchemist obtained through mysticism but of practical and theoretical knowledge about the basic elements of nature. The alchemical books also contain a lot of recipes for analysing metals and for purifying them. Most of them refer to methods of discerning through physical and chemical experiments between fake and real gold but at the same time they provide analytical methods for discovering the qualities of matter.

Mining and metallurgy

The theoretical and practical knowledge of the alchemist, dismissed by the Schools and the Church, became a significant part of mining and metallurgy literature. The mining and metallurgy literature does not use the alchemical "Decknamen" anymore. Out of all alchemical processes and aims, the metallurgy literature kept only those that deal with purification and testing of metals. These alchemical processes for refining metals come to be used by practitioners in mine-working. As a consequence a rich literature appears that describe in detail the complex recipes that have to be followed.[25] Because of the flourishing of the practical mining literature the humanists come to be interested in mining technology such that scholarly treatises on mining technology that appear not only describe but also systematize and bring arguments in favor of technology.

The most influential humanist in the domain of technology is Georgius Agricola. Agricola worked initially as a translator of Galen and

Hippocrates and was interested in philology. He writes the first scholarly book on mining, *De re metallica* published in 1556, whose main importance is the creation of a Latin vocabulary for mining and as such he elevated the art of mining to a learned subject. His book remains the authoritative text on mining for many years. Agricola used logic and scholastic distinctions as well as quotes from Greek and Latin classics, the book being a real scholarly work written for other scholars and not for actual miners. Even if he visited mines as a physician, he did not have a practical knowledge about mining. If one examines its drawings of mining mechanisms, one will observe that a lot of them are not going to work. The book contains descriptions of how to find, how to open and how to work mines, the various machines that are needed and various metallurgical processes. It also contains many drawings and in this respect it is similar to the books written by the actual artisans. Georgius Agricola begins his *De re metallica* with a rationale that explain the importance of mining for acquisition of knowledge and how much knowledge is involved in mining. He defends the art of mining on the model of the Roman author Columbella's defence of agriculture. His first book out of twelve consists of examining the arguments against the art of mining, including general arguments against technology as such that Agricola rejects and brings his own counterarguments:

> Any persons hold the opinion that the metal industries are fortuitous and that the occupation is one of sordid toil, and altogether a kind of business requiring not so much skill as labour. [...] there are many arts and sciences of which a miner should not be ignorant. First, there is Philosophy, that he may discern the origin, cause and nature of subterranean things.[26]

The miner has to know many learned subjects in order to be able to pursue his goals. He has to know philosophy, medicine, astronomy, surveying, arithmetic, architecture, drawing, law and practical alchemy. Agricola argues for the profitability of mining and against the critics that affirm that "gems, metals, and other mineral products are worthless in themselves" and gold and silver are morally undesirable. He states that "If we remove metals from the service of man, all methods of protecting and sustained health and more carefully preserving the course of life are done away with."[27] He considers arguments regarding the danger of mining, the devastation of mining fields and the purpose of God to place metals underground. In the end of the first book Agricola shows that metals are necessary for physicians, painters, architects, merchants and argue that mining is an honorable occupation and it "is objectionable to nobody". As one sees, Agricola rejects Aristotelian arguments regarding the knowledge associated with technology, the value of utility and the honourability of a technological occupation. As the alchemists before him, he argues that technology is not just an art for doing things but also a source of knowledge.

An important idea that is depicted along Agricola's book is that technology, in this case mining and metallurgy, is a systematic endeavor that involves various craftsmen and various devices. Technology is not any more a craft that a single man can perform but it is a fine-tuned interdependent collective activity. Agricola's book shows a new approach to work that requires skilled specialists working together in a technological context. What Agricola did is to invent the technical handbook for a systematic technological endeavor.

Natural Magic

The philosophy of technology is created by corroboration of the arguments and purposes of these practical domains of natural philosophy such as mechanics, alchemy, mining and metallurgy. But the closest domain to what is now referred to as technology is natural magic:

> "Natural magic" pointed to the operative power inherent in technology, and offered a framework outside that of Aristotelian causality. By the turn of the seventeenth century, discussions of technology often adopted the name "magic" as "the practical part of natural philosophy"[28].

Natural magic aims at discovering and using the natural forces and elements for obtaining useful and marvelous effects through human industry. Natural magic is a Renaissance creation based on Neo-Platonism and hermetic traditions.

The humanists promoted the use of utilitarian magic aimed at changing the material world. In addition, they advocate the introduction in schools, beside the normal Aristotelian curricula, of liberal and mechanical arts. One such proposal comes from Antonio Averlino, known as Filarete, who envisaged a school in which "'some manual arts should be taught here' by craftsmen; these would include a master of painting, a silversmith, a master of carving in marble and one for wood, a turner, an iron smith, a master of embroidery, a tailor, a pharmacist, a glassmaker and a master of clay. [...] The other crafts are also necessary and noble"[29].

Masilio Ficino, the discoverer of Plato and hermetic tradition, was very interested in natural magic, the ways of using plants, stones and other natural object as modes of acting on nature without the use of demoniacal or angelical powers. He uses Neo-Platonist sources, Chaldean oracles and Aristotelian metaphysics in sustaining this mode of command over nature by using the sympathies that exist between natural objects. This natural magic can be seen as a form of occult technology that uses pre-existing "levers" in nature, hidden by the Creator at the moment of creation, in order to obtain the desired effects. Another point to be made about natural magic is that it focuses on the utility of knowing the natural laws. Ficino's Magus is not a detached observer of nature that pursues knowledge for its own sake but the knowledge should be useful, the Magus should be able to apply the knowledge. The books on natural magic not only deal with the similitude between natural objects that can be used by the Magus but also employ mechanics, mathematics, alchemy and every practical knowledge available at that time.[30] Cornelius Agrippa's *De Occulta Philosophia* (1533) discusses astrology, mathematics, mechanical marvels, numerology, universal harmony, the power of music and incantations, images for talismans, and the occult virtues in natural things.

Giambattista Della Porta's *Magia Naturalis* (1588) describes procedures for such diverse things as transmuting metals, producing exotic plants and animals through grafting and crossbreeding, cutting, conserving, and cooking meat, staving off baldness, eliminating wrinkles, and engendering beautiful children. Other important authors in the natural magic tradition that are also viewed as experimental scientists are Paracelsus (1493–1541), Jean Baptiste van Helmont (1579–1644), Girolamo Cardano (1501–1576), Francis Bacon (1561–1626), and John Dee (1527–1608).

The university mathematicians and the writers on natural magic shared a special interest in mathematics and established a link between natural philosophy, mathematics and technology. Natural philosophy is the Renaissance name for science. In the Aristotelian-Scholastic framework it has almost nothing to do with technology. As well, mathematics in universities is not particularly linked to the study of nature or to technology. Mathematics, physics and technology are methodologically different domains although in practice during Renaissance humanists and scholars mixed these domains in various ways such that at the end of the period Galileo equates the study of natural motion with the study of mechanics and think of all universe as mathematically designed. The Magi and alchemists argue for the use of mathematics in natural magic and use quantitative methods in alchemical experiments. The mathematicians in Padua, the Oxford calculators[31] and their followers[32] try to establish mathematical laws for describing motion, thus creating the modern field of mechanics that brings together natural philosophical considerations, mathematics, and mechanisms. The extensive use of mathematics both in natural philosophy and in technology broadly conceived is due to Platonic tradition that represents an alternative to the mainstream Aristotelian teaching.

Artificial Revelation: Scientific Instruments

Along with the extensive praise of mathematics, another important characteristic of Renaissance books pertaining to technology is the invention of a new technological field, that of scientific instruments. An important feature of Galileo's works is the extensive use of experiments as well as the construction of scientific instruments. In the *Dialogue Concerning Two New Sciences* a lot of experiments that sustain his theoretical claims are used and Galileo designs mechanical devices that have no other purpose than that of demonstrating physical laws. Although experiments and mechanical devices are important they are not, at least declaratively, a primary source of knowledge. In many places in his work Galileo states that, although he performs the experiments, his claims have to be deduced theoretically from the principles. Therefore, experiments are only didactic aids:

> Even without further experiment, it is possible to prove clearly, by means of a short and conclusive argument, that a heavier body does not move more rapidly than a lighter one (62) [...] without depending upon the above experiment, which is doubtless very conclusive, it seems to me that it ought not to be difficult to establish such a fact by reasoning alone. (135) [...] to understand why this happens far outweighs the mere information obtained by the testimony of others or even by repeated experiment.[33]

Despite these declarations that belittle the use of experiments and scientific instruments, Galileo gives detailed descriptions of experimental settings, on how to construct scientific instruments and he is well aware of the importance of the observations and the knowledge he obtained through experiments. Derek de Solla Prince called Galileo's use of telescope "the principle of *artificial revelation*" that tremendously expanded the world, creating new domains of inquiry:

> The magnitude of this discovery cannot be overemphasized. That the Moon had mountains was an important discovery, but faded to relative triviality when compared with the nature of the experience itself. Galileo realized that he had manufactured for himself a revelatory knowledge of the universe that made his poor brain mightier than Plato or Aristotle and all the Church Fathers put together.[34]

A concern regarding the instruments that Galileo and his contemporaries have is to assure their readers that the observations are not artifacts.[35] A contemporary of Galileo, the Jesuit astronomer Christoph Scheiner, who makes similar observation in the same time as Galileo, is more concerned to demonstrate the reality of his observations and distinguish them from the inevitable errors of early telescopes:

> The images Scheiner was studying on walls or sheets of paper were not of sunspots but of flaws in the lenses. [...] He used the projection system not to make pictures of sunspots, but to map out how the optical artifacts produced by the telescope looked, and then to demonstrate that sunspots were clearly distinct from those artifacts. [...] Scheiner seemed much more concerned than Galileo with responding to possible philosophical objections to his use of the telescope, and described the painstaking procedures he followed to prove that the spots were not optical artifacts.[36]

All data obtained through experiments are to a certain extent "fabricated" in the sense that they do not naturally appear in everyday experience and they require special practical skills to operate the instruments and perceptual skills to extract the relevant data. Also, the data obtained require further interpretation. For example, Scheiner interpreted the sunspots as being planets revolving around the Sun as the available data were indecisive. And given the available instruments, all the experimental results were highly erroneous.

The books of alchemy also contain full descriptions of instruments as well as the methods of using and producing them. The instruments are not only tools employed for obtain various substances but they also serve as scientific instruments, i.e. tools for obtaining theoretical knowledge:

> The techniques of mineral testing and analysis were not employed by medieval alchemists merely as empirical means for attaining precious metals. By the late Middle Ages, these techniques had already evolved into tools for the experimental investigation of nature.[37]

Conclusion

In the beginning of the Renaissance the intellectual realm was dominated by Aristotelian thinking. That provided clear-cut conceptual distinctions regarding every domain of human endeavor. One of the most powerful distinctions was the classification of human knowledge into three main classes: knowledge about nature, knowledge about human action, and knowledge about human production. The first type of knowledge is the "proper" knowledge and includes mainly physics and metaphysics. The second type of knowledge is the practical one, in the sense of moral action and the search for the good life. The third type of knowledge, *techne*, regards the skills of making artifacts, the knowledge of producing. *Techne* is the domain that comprises, in contemporary terms, both technology and fine arts. *Techne* aims at imitating and perfecting nature in a narrow sense, the latter being well delimited and comprising what usually and normally happens. Knowledge is to be obtained by observation, without the observer's intervention. The artisans and their knowledge are, thus, despised.

All those characteristics that pertain to *techne* are remodeled during the Renaissance so that in the time of Bacon and Descartes one can speak of a well-established domain of autonomous technology, the domain of mechanical arts that comprise the production of useful artifacts. The products of technology are no longer subjected to the comparison with nature because they are original creations. The artisans gain a higher status as their knowledge, different in kind, seemed more certain and more necessary that the knowledge of the Schools. The development of this technical knowledge creates a new mode of acquiring and validating knowledge. The interventions in nature become necessary; the use of tools and mathematics in science becomes desirable. Alternatives to Aristotle's teachings are being searched for. Therefore, the Renaissance creates the conditions for the development of the modern understanding of technology as applied mathematical science and of experimental science.

Acknowledgements*: This paper was made within the project "Transnational Network of Integrated Postdoctoral Research in Science Communication. Institutional Development (postdoctoral school) and scholarship program (CommScie)" supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU ID 63663*

---

[1] Paul F. Grendler, "Renaissance", in Jonathan Dewald, ed., *Europe 1450 to 1789: Encyclopedia of the Early Modern World*, vol. 5 (London: Charles Scribner's Sons, 2004), 177-185.

[2] Jonathan Sawday, *The Engines of Imagination* (London: Routledge, 2007), xvii.

[3] Not an original work of Aristotle.

[4] "All teachers, whether Catholic or Protestant, Northern or Southern European, could agree with the Jesuit *Ratio studiorum* (Plan of Studies) of 1586, their manual of instruction, in holding that, at least in the classroom, 'in logic, natural philosophy, morals and metaphysics, the doctrine of Aristotle is to be followed'". See Daniel Garber, "Physics and Foundations", in Park, Katharine and Daston, Loraine, *The Cambridge History of Science, Volume 3: Early Modern Science* (Cambridge: Cambridge University Press, 2008), 26.

[5] Edgar Zilsel, "The Sociological Roots of Science", in *Social Studies of Science* 30, no. 6 (2000): 935.

[6] Wolfgang Lefevre, *Picturing Machines 1400-1700* (Cambridge: MIT Press, 2004), 13.

[7] Pamela O. Long, *Openness, Secrecy, Authorship: Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance* (Baltimore: The Johns Hopkins University Press, 2001), 104.

[8] Other ancient sources, like Plato and Scepticism, are not so widely spread and they are not taught in schools. Nevertheless, during the Renaissance, their influence increases among humanists and some of their ideas back up the new conceptualization of technology.

[9] In 1335 Guido of Vigevano, physician and engineer, write what is thought to be the first such book, *Texaurus Regis Francie Aquisitionis Terre Sancte de ultra Mare*, a "crusade book"

mean to help King Philip IV of France to conquer the Holy Land. This kind of book became familiar during the Renaissance: *Bellifortis* from 1405, by Conrad Kyeser; *Bellicorum instrumentorum liber* from 1430, by Giovanni Fontana; *Liber tertius* from 1430, by Mariano Taccola; *Trattato di Architettura* from 1462, by Antonio Averlino known as Filarete; *De re militari* from 1466, by Roberto Valturio; the *Büchsenmeisterbuch* from 1475, by Johannes Formschneider; *Trattati di architettura ingegneria* from 1484, by Francesco di Giorgio Martini; *Zeughausinventar* from 1489, by Ulrich Bessnitzer; *De la pirotechnia* from 1540, by Vannoccio Biringuccio; *De Subtilitate* from 1554, by Geronimo Cardano; *Tre discorsi* from 1567, by Giuseppe Ceredi; *Theatrum Instrumentorum et Machinarum* from 1578, by Jacobus Bessonus; *Instruments mathematiques mechaniques* from 1584, by Jean Errard de Bar-le-Duc; *Le diverse et artificiose machine* from 1588, by Agostino Ramelli; *Novo Teatro Di Machine* from 1607, by Vittorio Zorca; and *Les Raisons des Forces Mouvantes* from 1615, by Salomon de Caus.

[10] Pamela O. Long, "Nature", in Dewald, Jonathan, ed., *Europe 1450 to 1700: Encyclopedia of the Early Modern World*, Vol. 4 (New York: Charles Scribner's Sons, 2004), 255, my emphasis.

[11] Nicolas of Cusa, Idiota de Mente, II, in *Complete Philosophical and Theological Treatises of Nicholas of Cusa*, trans. Jasper Hopkins (Minneapolis/Minnesota: The Arthur J. Banning Press, 2001).

[12] Antonio Perez Ramos, "Bacon's forms and the maker's knowledge tradition", in Markku Peltonen, ed., *The Cambridge Companion to Bacon* (New York: Cambridge University Press, 1996), 113.

[13] Mark J. Schiefsky, "Art and Nature in Ancient Mechanics", in Bernadette Bensaude-Vincent and William R. Newman, *The Artificial and the Natural* (Cambridge: MIT Press, 2007), 95.

[14] Galileo Galilei. *Dialogues Concerning Two New Sciences*, trans. Henry Crew and Alfonso de Salvio (n.d.: William Andrew Publishing, 1914 [1638]), 1.

[15] Michael S. Mahoney, "Drawing Mechanics", in Wolfgang Lefevre, ed., *Picturing Machines 1400-1700*. (Cambridge: MIT Press, 2004), 284-285.

[16] Galileo Galilei. *Dialogues Concerning Two New Sciences*, 4.

[17] Pamela O. Long, *Openness, Secrecy, Authorship*, 2.

[18] "In a work called *De Natura Rerum* (*On the nature of things*) he (Paracelsus) notes, "transmutation is when a thing loses its form or shape and is transformed so that it no longer displays at all its initial form and substance. [...] When a metal becomes glass or stone [...] when wood becomes charcoal [...] (or) [...] when cloth becomes paper [...] all of that is the transmutation of natural things.' By this definition almost everyone in the early modern period was engaged in alchemy." See Bruce T. Moran, "Alchemy", in Jonathan Dewald, ed. *Europe 1450 to 1700: Encyclopedia of the Early Modern World*, vol. 1 (New York: Charles Scribner's Sons, 2004), 34.

[19] "A variety of laboratory procedures, including the separation of metals, sublimations, and distillations, were generally described in alchemical terms, and alchemy had already for a long time been associated with making medicines." (Bruce T. Moran, "Alchemy", in Dewald, ed. *Europe 1450 to 1700*, 32.

[20] The most important Latin texts are *Liber de compositione alchimiae*, translated from Arab in 1144 by Robert of Chester, and *De diversis artibus* written around 1100-1120 by Theophilus Presbyter.

[21] *Minima naturalia* theory is based on Aristotle's claim that there is a minimum amount of prime matter that can hold a form. "It is obvious that neither flesh, bone, nor any such thing can be of indefinite size in the direction either of the greater or of the less. [...] even though the quantity separated out will continually decrease, still it will not fall below a

certain magnitude. [...] it is clear that from the minimum quantity of flesh no body can be separated out" (*Physics*, 187b-188a)

22 Pamela O. Long, *Openness, Secrecy, Authorship*, 146.

23 William R. Newman and Anthony Grafton, "Introduction: The Problematic Status of Astrology and Alchemy in Premodern Europe", in William R. Newman & Anthony Grafton, eds. *Secrets of Nature: Astrology and Alchemy in Early Modern Europe* (Cambridge: MIT Press, 2001), 18.

24 Lawrence M. Principe, "Apparatus and Reproducibility in Alchemy", in Frederic L. Holmes and Trevor H. Levere, *Instruments and Experimentation in the History of Chemistry* (Cambridge: MIT Press, 2000), pp. 69-70.

25 The author of *Feuerwerkbuch*, a treatise from 1420 "claims to have written the book because the technical details of gunpowder manufacture are too complex to remember without the help of writing: 'And thereupon since the subjects belonging to it [gunnery] are so many, which every good gunner should know, and which a master without writing cannot remember in his mind', all the necessary details are provided." (Pamela O. Long, *Openness, Secrecy, Authorship* , 119).

26 Georgius Agricola, *De re metallica*, trans. H.C.Hoover and L.H. Hoover (London: The Mining Magazine, 1912), 1-2.

27 *Idem*, 18.

28 Mary Henninger-Voss, "Technology", in Jonathan Dewald, ed. *Europe 1450 to 1700: Encyclopedia of the Early Modern World*, vol. 6, (London: Charles Scribner's Sons, 2004), 11.

29 Pamela O. Long, *Openness, Secrecy, Authorship*, 132.

30 "For the occult writer, Henry Cornelius Agrippa, drawing on this well of mystical lore, mechanism and magic were inseparable from one another". See Jonathan Sawday, *The Engines of Imagination* (London: Routledge, 2007), 186.

31 Thomas Bradwardine, William Heytesbury, Richard Swineshead and John Dumbleton.

32 Jean Buridan and Nicole Oresme.

33 Galileo Galilei, *Dialogues Concerning Two New Sciences*, trans. Henry Crew and Alfonso de Salvio (n.d.: William Andrew Publishing, 1914 [1638]), 276.

34 Derek de Solla Prince, "Notes Toward and Philosophy of the Science/Technology Interaction", in Rachel Laudan, ed., *The Nature of Technological Knowledge: Are Models of Scientific Change Relevant?* (Dartmouth: Reidel Publishing, 1984), 108.

35 Mario Biagioli, in *Galileo's Instruments of Credit* (Chicago: University of Chicago Press. 2006), 156, note 37, claims that even Galileo uses the argument of artefactual nature of telescopic observations against its Jesuit enemies: "In the dispute on comets of 1619–23, Galileo argued that the comets observed by the Roman Jesuits may have been not real physical objects but optical artifacts. Galileo's claim emerged in a context in which the Jesuits had been first to publish observations of the comets while Galileo had been sick and unable to produce a comparable body of observations."

36 Mario Biagioli, *Galileo's Instruments of Credit*, 200.

37 William R. Newman, "Alchemy, Assaying, and Experiment", in Frederic L. Holmes and Trevor H. Levere, *Instruments and experimentation in the history of chemistry* (Cambridge: MIT Press, 2000), 35.

References:

Agricola, Georgius. *De re metallica*. Translated by H.C. Hoover & L.H. Hoover. London: The Mining Magazine, 1912.

Anderson, R.G.W. "The Archaeology of Chemistry." In Frederic L. Holmes and Trevor H. Levere. *Instruments and Experimentation in the History of Chemistry*. Cambridge: MIT Press, 2000.

Aristotle. *Complete Works*. Edited by Jonathan Barnes. Princeton: Princeton University Press. 1991.

Biagioli, Mario. *Galileo's Instruments of Credit*. Chicago: University of Chicago Press. 2006.

Berryman, Sylvia. "Ancient Automata and Mechanical Explanation." *Phronesis* 48, no.4 (2003): 344-369.

Copenhaver, Brian P. and Chalres B. Schmitt. *A History of Western Philosophy – Volume 3: Renaissance Philosophy*. London: Oxford University Press, 1992.

Cusa, Nicolas of. *Idiota de Mente*, II. In *Complete Philosophical and Theological Treatises of Nicholas of Cusa*. Translated by Jasper Hopkins. Minneapolis/Minnesota: The Arthur J. Banning Press, 2001.

Dewald, Jonathan, ed. *Europe 1450 to 1789: Encyclopedia of the Early Modern World*, 6 volumes, London: Charles Scribner's Sons, 2004.

Galileo Galilei. *Dialogues Concerning Two New Sciences*. Translated by Henry Crew and Alfonso de Salvio, William Andrew Publishing, 1914 [1638].

Garber, Daniel. "Physics and Foundations.", In Katharine Park and Loraine Daston. *The Cambridge History of Science – Volume 3: Early Modern Science*. Cambridge: Cambridge University Press, 2008.

Grendler, Paul F. "Renaissance", in Jonathan Dewald, ed. *Europe 1450 to 1789: Encyclopedia of the Early Modern World*, vol. 5. London: Charles Scribner's Sons, 2004: 177-185.

Henninger-Voss, Mary. "Technology", in Jonathan Dewald, ed. *Europe 1450 to 1700: Encyclopedia of the Early Modern World*, vol. 6, London: Charles Scribner's Sons, 2004.

Lefevre, Wolfgang, ed. *Picturing Machines 1400-1700*. Cambridge: MIT Press, 2004.

Long, Pamela O. *Openness, Secrecy, Authorship: Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance*. Baltimore: The Johns Hopkins University Press, 2001.

Long, Pamela O. "Nature." In Dewald, Jonathan, ed. *Europe 1450 to 1700: Encyclopedia of the Early Modern World*, vol. 4. New York: Charles Scribner's Sons, 2004.

Mahoney, Michael S. "Drawing Mechanics." In Wolfgang Lefevre, ed. *Picturing Machines 1400-1700*. Cambridge: MIT Press, 2004.

McClellan III, E. James, and Harold Dorn. *Science and Technology in World History*. Baltimore: The Johns Hopkins University Press, 2006.

Moran, Bruce T. "Alchemy." In Jonathan Dewald, ed. *Europe 1450 to 1700: Encyclopedia of the Early Modern World*, vol. 1. New York: Charles Scribner's Sons, 2004: 32-35.

Murdoch, John E. "The Medieval and Renaissance Tradition of *Minima Naturalia*." In Lüthy, Christoph, John E. Murdoch, and William R. Newman, eds. *Late Medieval and Early Modern Corpuscular Matter Theories*. Leiden: Brill Academic Publishers, 2001.

Newman, William R. "Alchemy, Assaying, and Experiment." In Frederic L. Holmes and Trevor H. Levere. *Instruments and Experimentation in the History of Chemistry*. Cambridge: MIT Press, 2000.

Newman, William R. and Anthony Grafton. "Introduction: The Problematic Status of Astrology and Alchemy in Premodern Europe." In William R. Newman and Anthony Grafton, eds. *Secrets of Nature: Astrology and Alchemy in Early Modern Europe*. Cambridge: MIT Press, 2001.

Newman, William R. "Technology and Alchemical Debate in the Late Middle Ages." *Isis* 80, no. 3 (1989): 423-445.

Newman, William R. and Anthony Grafton, eds. *Secrets of Nature: Astrology and Alchemy in Early Modern Europe*. Cambridge: MIT Press, 2001.

Perez Ramos, Antonio. "Bacon's forms and the maker's knowledge tradition." In Markku Peltonen, ed. *The Cambridge Companion to Bacon*. New York: Cambridge University Press, 1996.

Principe, Lawrence M. "Apparatus and Reproducibility in Alchemy." In Frederic L. Holmes & Trevor H. Levere. *Instruments and Experimentation in the History of Chemistry*. Cambridge: MIT Press, 2000.

Sawday, Jonathan. *The Engines of Imagination*. London: Routledge, 2007.

Solla Price, Derek de. "Notes Toward and Philosophy of the Science/Technology Interaction", in Rachel Laudan, ed. *The Nature of Technological Knowledge: Are Models of Scientific Change Relevant?* Dartmouth: Reidel Publishing, 1984.

Schiefsky, Mark J. "Art and Nature in Ancient Mechanics." In Bernadette Bensaude-Vincent & William R. Newman. *The Artificial and the Natural*. Cambridge: MIT Press, 2007.

Winter, Thomas Nelson. *The* Mechanical Problems *in the Corpus of Aristotle*. Lincoln: DigitalCommons, University of Nebraska, 2007.

Zilsel, Edgar. "The Sociological Roots of Science". *Social Studies of Science* 30, no. 6 (2000): 935-949.